

IMAGE DISPLAY

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TECHNICAL FIELD

[0001] The present invention relates to image display apparatus and, more particularly, to a head- or face-mounted image display apparatus that can be retained on the observer's head or face.

BACKGROUND ART

[0002] Image display apparatus designed to observe an image of a single image display device with two eyes have heretofore been known in Japanese Patent Application Unexamined Publication Number [hereinafter referred to as "JP(A)"] 5-176260, 9-61748, 9-181998 and 9-181999.

[0003] An illuminating method for an image display apparatus designed to observe an image of a single image display device with two eyes has been known, for example, in JP(A) 7-318851.

[0004] Among them, the image display apparatus of JP(A) 5-176260 splits and folds light rays by a prism in the shape of an isosceles triangular prism and a mirror. Therefore, various aberrations are corrected by a lens placed in front of the pupil. This makes it difficult to correct aberrations, and at the same time, causes the apparatus to become large in size. In JP(A) 9-61748, display light from an LCD (liquid crystal display device) is split by using a half-mirror so as to be observed with two eyes. Because the display light is distributed to the left and right eyeballs, the image for observation becomes weak and dark. In JP(A) 9-181998 and 9-181999, because prisms are integrated, the prism structure is very large in size and requires a great deal of time and cost when it is produced by injection molding. In addition, correction of decentration aberrations is insufficient.

[0005] Regarding an illuminating method for use in a case where a display image from a single display device is observed with two eyes, when an arrangement such as that disclosed in JP(A) 7-318851 is adopted, because images led to the left and right eyes are in reversed relation to each other, the display image needs to be electrically switched for the left and right by the display device or other device.

DISCLOSURE OF THE INVENTION

[0006] The present invention was made in view of the above-described problems with the prior art, and an object of the present invention is to provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and in which a power is given to an optical path distributing means placed at the middle between the two eyes to facilitate the correction of various aberrations. In addition, an object of the present invention is to provide an illuminating method which is the most suitable for observation of a single panel (single image display device) with two eyes, and which can be used without the need to switch the display image for the left and right.

[0007] An image display apparatus according to the present invention provided to attain the above-described object has an image display device for displaying an image to be observed by an observer, an optical path distributing mirror for distributing the image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on the right-hand side of the optical path distributing mirror, and an ocular prism for the left eye that is placed on the left-hand side of the optical path distributing mirror.

[0008] The optical path distributing mirror has a mirror surface placed to face the image display device to reflect a display light beam emanating from the image display device so as to distribute the display light beam to the ocular prism for the right eye and the prism for the left eye. The mirror surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0009] The ocular prism for the right eye has a first surface through which the light beam of the optical path for the right eye reflected by the optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism.

[0010] The ocular prism for the left eye has a first surface through which the light beam of the optical path for the left eye reflected by the optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism.

[0011] At least the second surface of the ocular prism for the right eye, which is a reflecting surface, and the second surface of the ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0012] Another image display apparatus according to the present invention has an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing the image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on the right-hand side of the optical path distributing prism, and an ocular prism for the left eye that is placed on the left-hand side of the optical path distributing prism.

[0013] The optical path distributing prism has at least a first surface placed to face the image display device so that a display light beam emanating from the image display device enters the prism through the first surface, a second-first surface which reflects the optical path for the right eye entering through the first surface, a second-second surface which reflects the optical path for the left eye entering through the first surface, a third-first surface through which the light beam of the optical path for the right eye exits from the prism, and a third-second surface through which the light beam of the optical path for the left eye exits from the prism.

[0014] To form a relay image for the right eye from the image displayed by the image display device in the optical path for the right eye and to form a relay image for the left eye from the image displayed by the image display device in the optical path for the left eye, the optical path distributing prism is arranged so that at least the second-first surface and the second-second surface have a curved surface configuration that gives a power to the light beam, and the second-first surface and the second-second surface have the same surface configuration.

[0015] The ocular prism for the right eye has a first surface through which the light beam of the optical path for the right eye exiting from the third-first surface of the optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism.

[0016] The ocular prism for the left eye has a first surface through which the light beam of the optical path for the left eye exiting from the third-second surface of the optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism.

[0017] At least the second surface of the ocular prism for the right eye, which is a reflecting surface, and the second surface of the ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0018] With the above-described arrangement, the present invention can provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and the correction of various aberrations is facilitated by placing an optical path distributing mirror or an optical path distributing prism at the middle between the two eyes. Further, it is possible to obtain an illuminating arrangement which is the most suitable for observation of a single panel with two eyes, and which can be used in the above-described arrangement without the need to switch the display image for the left and right.

[0019] Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

[0020] The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a ray path diagram of an image display apparatus according to Example 1 of the present invention. Fig. 2 is a ray path diagram of an image display apparatus according to Example 2 of the present invention. Fig. 3 is a ray path diagram of an image display apparatus according to Example 3 of the present invention. Fig. 4 is a ray path diagram of an image display apparatus according to Example 4 of the present invention. Fig. 5 is a ray path diagram of an image display apparatus according to Example 5 of the present invention. Fig. 6 is a ray path diagram of an image display apparatus according to Example 6 of the present invention. Fig. 7 is a ray path diagram of an image display apparatus according to Example 7 of the present invention. Fig. 8 is a ray path diagram of an image display apparatus according to Example 8 of the present invention. Fig. 9 is a ray path diagram of an image display apparatus according to Example 9 of the present invention. Fig. 10 is a ray path diagram of an image display apparatus according to Example 10 of the present invention. Fig. 11 is a ray path diagram of an image display apparatus according to Example 11 of the present invention. Fig. 12 is a ray path diagram of an image display apparatus according to Example 12 of the present invention. Fig. 13 is a ray path diagram of an image display apparatus according to Example 13 of the present invention. Fig. 14 is a ray path diagram of an image display apparatus according to Example 14 of the present invention. Fig. 15 is a ray path diagram of an image display apparatus according to Example 15 of the present invention. Fig. 16 is a diagram for describing an image display apparatus according to Example 16 of the present invention. Fig. 17 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 17 of the present invention. Fig. 18 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 18 of the present invention. Fig. 19 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 19 of the present invention. Fig. 20 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 20 of the present invention. Fig. 21 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 21 of the present invention. Fig. 22 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 22 of the present invention. Fig. 23 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 23 of the present invention. Fig. 24 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 24 of the present invention. Fig. 25 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 25 of the present invention. Fig. 26 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 26 of the present invention. Fig. 27 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 27 of the present invention. Fig. 28 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 28 of the present invention. Fig. 29 is a ray path diagram of image display apparatus according to Examples 29 and 30 of the present invention. Fig. 30 is a diagram for describing the definition of parameters α and β . Fig. 31 is a diagram for describing the definition of parameters L and D . Fig. 32 is a horizontal sectional view of an optical system for a right eye according to Example 29. Fig. 33 is a horizontal sectional view of an optical system for a right eye according to Example 30. Fig. 34 is an aberrational diagram showing lateral aberrations in the optical system of Example 16. Fig. 35 is an aberrational diagram showing lateral aberrations in the optical system of Example 20. Fig. 36 is an aberrational diagram showing lateral aberrations in the optical system of Example 22. Fig. 37 is an aberrational diagram showing lateral aberrations in the optical system of Example 29. Fig. 38 is an aberrational diagram showing lateral aberrations in the optical system of Example 30. Fig. 39 is a diagram for describing an arrangement of the image display apparatus according to the present invention when arranged to allow see-through observation. Fig. 40 is a perspective view illustrating the structure of an organic EL image display device. Fig. 41 is a view showing the way in which the image display apparatus according to the present invention is fitted on an observer's head.

BEST MODE OF CARRYING OUT THE INVENTION

[0022] The image display apparatus according to the present invention will be described below by way of examples. Figs. 1 to 15 are ray path diagrams respectively showing image display apparatus according to Examples 1 to 15 of the present invention.

[0023] In Example 1 shown in Fig. 1, a right eye of an observer is denoted by ER, and a left eye of the observer is denoted by EL. An image display device of an image display apparatus is denoted by reference numeral 3. An exit pupil for the right eye is denoted by 4R, and an exit pupil for the left eye is denoted by 4L. A decentered prism member placed in front of the right eye as an optical system for the right eye is denoted by 2R, and a decentered prism member placed in front of the left eye as an optical system for the left eye is denoted by 2L. In addition, an optical path distributing mirror placed at the middle between the

two eyes is denoted by 1. The decentered prism members 2R and 2L are made of a transparent medium having a refractive index larger than 1. In the following description, surfaces stated to be reflecting surfaces are mirror surfaces formed by providing mirror coatings on the relevant surfaces of the decentered prism members except totally reflecting surfaces.

[0024] Example 1 is arranged as shown in Fig. 1, which shows a horizontal section (YZ-section) thereof. The optical path distributing mirror 1 at the middle between the two eyes has a reflecting surface 1R for a right optical path and a reflecting surface 1L for a left optical path, which have symmetric configurations with respect to a plane of symmetry between the two eyes (i.e. a plane passing through the center of a line segment connecting the respective centers of the exit pupil 4R for the right eye and the exit pupil 4L for the left eye at right angles to the line segment).

[0025] The decentered prism member 2R, which constitutes an optical system for the right eye, and the decentered prism member 2L, which constitutes an optical system for the left eye, have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L). The second surface 22R (22L) and the fourth surface 24R (24L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0026] The image display device 3 is placed to face the optical path distributing mirror 1 on the observer side of the latter. The exit pupils 4R and 4L are located approximately in the same plane, facing the fourth surfaces 24R and 24L of the decentered prism members 2R and 2L, respectively. The surfaces 21R to 24R, 21L to 24L, 1R and 1L of the decentered prism members 2R and 2L and the optical path distributing mirror 1 are formed from free-form surfaces expressed by equation (a), which will be described later. Each of the free-form surfaces can be replaced with a spherical surface including a plane surface, an aspherical surface, an anamorphic surface, or an anamorphic aspherical surface.

[0027] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the reflecting surface 1R of the optical path distributing mirror 1 and reflected by the reflecting surface 1R so as to enter the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism and is incident on the second surface 22R at an incident angle not less than the critical angle, thereby being totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. It should be noted that no intermediate image is formed in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0028] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In addition, because one surface of the optical path distributing mirror 1 is used to distribute display light to the left and right optical paths, the production is easier than in the case of a prism having a multiplicity of surfaces, and the weight of the display apparatus can be reduced, advantageously. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, it becomes possible to correct decentration aberrations very favorably.

[0029] Further, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the optical path distributing mirror 1 at the middle between the two eyes.

[0030] Fig. 2 shows a horizontal section (YZ-section) of Example 2. Example 2 has a common negative lens 5 inserted in the optical path from the image display device 3 to the reflecting surface 1R for the right optical path and the reflecting surface 1L for the left optical path of the optical path distributing mirror 1 in the arrangement of Example 1. The arrangement of the rest of Example 2 and the optical paths therein are the same as in Example 1. No intermediate image is formed as in the case of Example 1. A diffractive optical element or a lenticular lens may be used in place of or in addition to the negative lens 5. By inserting the negative lens 5 or the like between the image display device 3 and the optical path distributing mirror 1, aberrations can be corrected even more favorably. The use of a diffractive optical element or a lenticular lens allows the left and right optical paths to be divided from each other even more easily.

[0031] Fig. 3 shows a horizontal section (YZ-section) of Example 3. Example 3 uses an optical path distributing prism 10 formed from a decentered prism member with five surfaces in place of the optical path distributing mirror 1 placed at the middle between the two eyes in Examples 1 and 2. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 and 2.

[0032] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a transmitting surface 13L for the left optical path and a transmitting surface 13R for the right optical path, which are located on the observer sides of the second surfaces 12R and 12L. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R and 12L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The third surfaces 13L and 13R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0033] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0034] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0035] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0036] Fig. 4 shows a horizontal section (YZ-section) of Example 4. Example 4 uses an optical path distributing prism 10 formed from a decentered prism member with five surfaces in place of the optical path distributing mirror 1 placed at the middle between the two eyes in Examples 1 and 2. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 and 2. A major difference from Example 3 is in the placement of the image display device 3. In Example 4, the image display device 3 is disposed on the observer side of the optical path distributing prism 10.

[0037] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a third surface 13R as a transmitting surface for the right optical path and a third surface 13L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the side thereof remote from the observer; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on respective sides of the third surfaces 13R and 13L remote from the observer. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0038] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0039] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces

and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JPA) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0040] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0041] Fig. 5 shows a horizontal section (YZ-section) of Example 5. Example 5 uses an optical path distributing prism 10 formed from a decentered prism member with three surfaces in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Examples 3 and 4. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 to 4.

[0042] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof and function as totally reflecting surfaces; a transmitting surface 13L for the left optical path, which is the identical with the second surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path, which is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0043] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0044] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces of the optical path distributing prism 10 are also used as reflecting surfaces, the number of effective surfaces of the optical path distributing prism 10 is only three. Therefore, the production is very easy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JPA) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0045] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0046] Fig. 6 shows a horizontal section (YZ-section) of Example 6. Example 6 uses an optical path distributing prism 10 formed from a decentered prism member with six surfaces in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Examples 3 and 4. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 to 5.

[0047] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has six surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface facing the first surface 11 and also

facing the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on both sides between the second surface 12 and the third surfaces 13R and 13L. The first surface 11 and the second surface 12 each have a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the fourth surfaces 14L and 14R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0048] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10, which is common to the left and right. The incident light is reflected by the second surface 12, which is common to the left and right. The reflected light is incident on the third surface 13R as a reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0049] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the optical path distributing prism 10 is arranged to reflect light twice therein, it is possible to correct decentration aberrations very favorably. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12, 13R and 13L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0050] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0051] Fig. 7 shows a horizontal section (YZ-section) of Example 7. In Example 7, a decentered prism member 2R constituting an optical system for the right eye and a decentered prism member 2L constituting an optical system for the left eye have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), a fourth surface 24R (24L), and a fifth surface 25R (25L). The third surface 23R (23L) and the fifth surface 25R (25L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0052] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 4 (Fig. 4). The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a third surface 13R as a transmitting surface for the right optical path and a third surface 13L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on the observer sides of the third surfaces 13R and 13L, respectively. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0053] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path

from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0054] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0055] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0056] Fig. 8 shows a horizontal section (YZ-section) of Example 8. Example 8 uses an optical path distributing prism 10 formed from a decentered prism member with three surfaces as in the case of Example 5 (Fig. 5), in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Example 7. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Example 7.

[0057] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 5 (Fig. 5). The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof and function as totally reflecting surfaces; a transmitting surface 13L for the left optical path, which is the identical with the second surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path, which is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0058] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0059] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces of the optical path distributing prism 10 are also used as reflecting surfaces, the number of effective surfaces of the optical path distributing prism 10 is only three. Therefore, the production is very easy. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0060] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be

made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0061] Fig. 9 shows a horizontal section (YZ-section) of Example 9. Example 9 uses an optical path distributing prism 10 formed from a decentered prism member with six surfaces as in the case of Example 6 (Fig. 6) in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Example 7. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Example 7.

[0062] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 6 (Fig. 6). The optical path distributing prism 10 has six surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a second surface 12R as a reflecting surface facing the first surface 11 on the side of the first surface 11 remote from the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the side thereof remote from the observer; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on both sides between the second surface 12 and the third surfaces 13R and 13L. The first surface 11 and the second surface 12 each have a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the fourth surfaces 14L and 14R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0063] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10, which is common to the left and right. The incident light is reflected by the second surface 12, which is common to the left and right. The reflected light is incident on the third surface 13R as a reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0064] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing five reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the optical path distributing prism 10 is arranged to reflect light twice therein, it is possible to correct decentration aberrations very favorably. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12, 13R and 13L of the optical path distributing prism 10 it becomes possible to correct decentration aberrations very favorably.

[0065] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0066] Fig. 10 shows a horizontal section (YZ-section) of Example 10. In Example 10, a decentered prism member 2R for the right eye and a decentered prism member 2L for the left eye, which are formed from respective decentered prism members of the same configuration having three surfaces, are placed in symmetry with respect to the plane of symmetry between the two eyes, in place of the decentered prism member 2R for the right eye and the decentered prism member 2L for the left eye, which are formed from respective decentered prism members each having four surfaces in Example 8 (Fig. 8). The optical path distributing prism 10 is the same as in Example 8. Light entering the decentered prism member 2R through a first surface 21R thereof is reflected by a second surface 22R. The reflected light is refracted by a third surface 23R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye. The rest of Example 10 is the same as that in Example 8.

[0067] Fig. 11 shows a horizontal section (YZ-section) of Example 11. In Example 11, a decentered prism member 2R for the right eye and a decentered prism member 2L for the left eye, which are formed from respective decentered prism members of the same configuration having three surfaces, are placed in symmetry with respect to the plane of symmetry between the two eyes, in place of the decentered prism member 2R for the right eye and the decentered prism member 2L for the left eye, which are formed from

respective decentered prism members each having four surfaces in Example 7 (Fig. 7). The optical path distributing prism 10 is the same as in Example 7. Light entering the decentered prism member 2R through a first surface 21R thereof is reflected by a second surface 22R. The reflected light is refracted by a third surface 23R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye. The rest of Example 11 is the same as that in Example 7.

[0068] Fig. 12 shows a horizontal section (YZ-section) of Example 12. Example 12 uses an optical path distributing prism 10 formed from a decentered prism member having seven surfaces. A decentered prism member 2R constituting an optical system for the right eye and a decentered prism member 2L constituting an optical system for the left eye have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L).

[0069] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has seven surfaces: a first surface 11 as a transmitting surface located on the side remote from the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the side remote from the observer; a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on the observer sides of the third surfaces 13R and 13L, respectively; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on the observer sides of the fourth surfaces 14R and 14L. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L, the fourth surfaces 14L and 14R and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0070] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light is incident on the third surface 13R as the subsequent reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R and back-reflected thereby. The reflected light is incident on the third surface 23R and back-reflected thereby. The reflected light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0071] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R, 12L, 13R and 13L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R, 12L, 13R and 13L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0072] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0073] In this example, none of the optical path distributing prism 10 and the decentered prism members 2R and 2L use a totally reflecting surface. When a totally reflecting surface is used, the incident angle of light rays needs to be increased greatly in order to satisfy the condition for total reflection. However, when a power is given to a surface having a large incident angle, decentration aberrations occur to a considerable extent. Therefore, only a weak power can be given to such a surface. In this example, which does not use such a totally reflecting surface, however, powers can be distributed equally to various surfaces by utilizing ordinary reflection. Thus, it is possible to correct decentration aberrations very favorably. In addition, because the optical path is arranged to cross itself within each of the decentered prisms 10 2R and 2L, it is possible to increase the optical path length of the ocular prism. Therefore, an intermediate image can be formed at a position within the ocular prism. Accordingly, it is possible to lengthen the overall distance from the intermediate image to the display device and to set a weak power for the optical path distributing prism 10. Consequently, it is possible to ensure favorable image-forming performance.

[0074] Examples 13 to 15 are examples relating to an illuminating optical system for the image display device 3. Example 13 shown in Fig. 13 is an example in which a transmission type LCD (liquid crystal display device) is used as the image display device 3 in the arrangement of the left and right optical systems in Example 5 shown in Fig. 5, and illuminating light sources 6R and 6L for the right and left optical paths are placed at the back of the image display device 3 (on the side remote from the optical path distributing prism 10), and further a condensing Fresnel lens 7 is placed between the image display device 3 and the light sources 6R and 6L.

[0075] In this example, illuminating light from the illuminating light source 6L for the left optical path is incident on the image display device 3 after being condensed by the Fresnel lens 7. Display light from the image display device 3 reaches the observer's left eye EL through the optical path for the left eye in Fig. 5 and projects an enlarged image of the image display device 3. Illuminating light from the illuminating light source 6R for the right optical path is incident on the image display device 3 after being condensed by the Fresnel lens 7. Display light from the image display device 3 reaches the observer's right eye ER through the optical path for the right eye in Fig. 5 and projects an enlarged image of the image display device 3.

[0076] In this case, the left and right optical systems share the illuminating optical system 7 for the left and right eyes, which is used for a single image display device (LCD) 3 common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, a half-mirror is not used in the illuminating optical system either, and it is therefore possible to display a very bright image.

[0077] Example 14 shown in Fig. 14 is an example in which a reflection type LCD (liquid crystal display device) 3' is used as the image display device 3 in the arrangement of the left and right optical systems in Example 6 shown in Fig. 6. In addition, illuminating light sources 6R and 6L for the right and left optical paths are placed so as to be capable of illuminating the reflection type LCD 3' across the optical path distributing prism 10, and the second surface 12 of the optical path distributing prism 10 is formed as a half-mirror surface or a mirror surface partly provided with holes for passing light, thereby illuminating the reflection type LCD 3' with illuminating light from the light sources 6R and 6L through the second surface 12 and the first surface 11.

[0078] In this example, illuminating light from the illuminating light source 6L for the left optical path passes through the half-mirror surface, which forms the second surface 12 of the optical path distributing prism 10, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12 of the optical path distributing prism 10. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's left eye EL through the optical path for the left eye in Fig. 6 and projects an enlarged image of the image display device 3. Similarly, illuminating light from the illuminating light source 6R for the right optical path passes through the half-mirror surface, which forms the second surface 12 of the optical path distributing prism 10 or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12 of the optical path distributing prism 10. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's right eye ER through the optical path for the right eye in Fig. 6 and projects an enlarged image of the image display device 3.

[0079] In this case, the left and right optical systems share the illuminating optical system for the left and right eyes, which is used for a single reflection type LCD 3' common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, the optical path distributing prism (also used as an illuminating prism) 10 has six effective surfaces, and it is therefore possible to illuminate the reflection type LCD 3' uniformly and to correct decentration aberrations even more favorably.

[0080] Example 15 shown in Fig. 15 is an example in which a reflection type LCD 3' is used as the image display device 3 in the arrangement of the left and right optical systems in Example 4 shown in Fig. 4. In addition, illuminating light sources 6R and 6L for the left and right optical paths are placed so as to be capable of illuminating the reflection type LCD 3' across the optical path distributing prism 10, and the second surfaces 12L and 12R of the optical path distributing prism 10 for the left and right optical paths are formed as half-mirror surfaces or mirror surfaces partly provided with holes for passing light, thereby illuminating the reflection type LCD 3' with illuminating light from the light sources 6R and 6L through the second surfaces 12L and 12R and the first surface 11.

[0081] In this example, illuminating light from the illuminating light source 6L for the left optical path passes through the half-mirror surface, which forms the second surface 12R of the optical path distributing prism 10 for the optical path for the right eye, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12R. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's left eye EL through the optical path for the left eye in Fig. 4 and projects an enlarged image of the image display device 3. Similarly, illuminating light from the illuminating light source 6R for the right optical path passes through the half-mirror surface, which forms the second surface 12L of the optical path distributing prism 10 for the optical path for the left eye, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12L. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's right eye ER through the optical path for the right eye in Fig. 4 and projects an enlarged image of the image display device 3.

[0082] In this case, the left and right optical systems share the illuminating optical system for the left and right eyes, which is used for a single reflection type LCD 3' common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, the left and right optical systems share the entrance and exit surfaces of the illuminating optical system while sharing the optical path distributing prism 10 and the illuminating optical system, thereby allowing the optical path distributing prism 10 to be reduced in both size and weight.

[0083] It should be noted that a transmission or reflection type image display device 3 can be illuminated not only in the examples shown in Figs. 4 to 6 but also in the other examples described above by using illuminating light sources 6R and 6L for the right and left optical paths, placing a condensing Fresnel lens 7, or forming a reflecting surface as a half-mirror surface or a mirror surface partly provided with holes for passing light, as shown in Figs. 13 to 15.

[0084] Incidentally, it is desirable to use surfaces with a rotationally asymmetric curved surface configuration that corrects decentration aberrations as the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, the surfaces 11, 12, 12R, 12L, 13R, 13L, 14R and 14L of the optical path distributing prism 10, the surfaces 21R to 25R of the decentered prism member 2R of the ocular optical system for the right eye, and the surfaces 21L to 25L of the decentered prism member 2L of the ocular optical system for the right eye.

[0085] Basically, the decentered prism member 2R for the right eye, the decentered prism member 2L for the left eye, the optical path distributing prism 10 and the optical path distributing mirror 1 in the present invention are decentered optical systems. It is desirable that these decentered optical systems be arranged so as to include at least one optical surface with a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0086] In a case where a decentered optical system is used, for example, as a viewing optical system of a head-mounted image display apparatus, it is necessary in order to eliminate a dead space and minimize the overall size of the apparatus to position an image display device and each optical surface constituting the decentered optical system so that the constituent elements are accommodated in the apparatus in as compact a form as possible. Consequently, the optical system must inevitably be decentered three-dimensionally, and this causes rotationally asymmetric aberration to occur. It is impossible to correct the rotationally asymmetric aberration by only a rotationally symmetric optical system. The best surface configuration for correcting the rotationally asymmetric aberration due to three-dimensional decentration is a rotationally asymmetric surface. Therefore, in the image display apparatus according to the present invention, it is desirable to use a rotationally asymmetric curved surface configuration that corrects decentration aberrations as the configuration of at least one surface, preferably at least one reflecting surface, among the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, the surfaces 11, 12, 12R, 12L, 13R, 13L, 14R and 14L of the optical path distributing prism 10 the surfaces 21R to 25R of the decentered prism member 2R of the ocular optical system for the right eye and the surfaces 21L to 25L of the decentered prism member 2L of the ocular optical system for the right eye.

[0087] A free-form surface used in the present invention as a surface with a rotationally asymmetric curved surface configuration is defined by the following equation. The Z-axis of the defining equation is the axis of a free-form surface. EMI59.1

[0088] In the equation (a), the first term is a spherical surface term, and the second term is a free-form surface term.

[0089] In the spherical surface term: c: the curvature at the vertex k: a conic constant $r = 2\sqrt{1 + k}$
($X^2 + Y^2$)

[0090] The free-form surface term is given by EMI59.2 EMI60.1 where C_j (j is an integer of 2 or higher) are coefficients.

[0091] In general, the above-described free-form surface does not have planes of symmetry in both the XZ- and YZ-planes. However, a free-form surface having only one plane of symmetry parallel to the YZ-plane is obtained by making all terms of odd-numbered degrees with respect to X zero. A free-form surface having only one plane of symmetry parallel to the XZ-plane is obtained by making all terms of odd-numbered degrees with respect to Y zero.

[0092] In addition, free-form surfaces as the above-described surfaces with a rotationally asymmetric curved surface configuration may be defined by Zernike polynomials. That is, the configuration of a free-form surface may be defined by the following equation (b). The Z-axis of the defining equation (b) is the axis of Zernike polynomial. A rotationally asymmetric surface is defined by polar coordinates of the height of the Z-axis with respect to the XY-plane. In the equation (b), A is the distance from the Z-axis in the XY-plane, and R is the azimuth angle about the Z-axis, which is expressed by the angle of rotation measured from the Z-axis. $x = R \cos(A)$ $y = R \sin(A)$ "(b)" $Z = D_2 + D_3R\cos(A) + D_4R\sin(A) + D_5R^2\cos(2A) + D_6R^2\sin(2A) + D_7R^3\cos(3A) + D_8R^3\sin(3A) + D_9R^4\cos(4A) + D_{10}R^4\sin(4A) + D_{11}R^5\cos(5A) + D_{12}R^5\sin(5A) + D_{13}R^6\cos(6A) + D_{14}R^6\sin(6A) + D_{15}R^7\cos(7A) + D_{16}R^7\sin(7A) + D_{17}R^8\cos(8A) + D_{18}R^8\sin(8A) + D_{19}R^9\cos(9A) + D_{20}R^9\sin(9A) + D_{21}R^{10}\cos(10A) + D_{22}R^{10}\sin(10A) + D_{23}R^{11}\cos(11A) + D_{24}R^{11}\sin(11A) + D_{25}R^{12}\cos(12A) + D_{26}R^{12}\sin(12A) + D_{27}R^{13}\cos(13A) + D_{28}R^{13}\sin(13A) + D_{29}R^{14}\cos(14A) + D_{30}R^{14}\sin(14A) + D_{31}R^{15}\cos(15A) + D_{32}R^{15}\sin(15A) + D_{33}R^{16}\cos(16A) + D_{34}R^{16}\sin(16A) + D_{35}R^{17}\cos(17A) + D_{36}R^{17}\sin(17A) + D_{37}R^{18}\cos(18A) + D_{38}R^{18}\sin(18A) + D_{39}R^{19}\cos(19A) + D_{40}R^{19}\sin(19A) + D_{41}R^{20}\cos(20A) + D_{42}R^{20}\sin(20A) + D_{43}R^{21}\cos(21A) + D_{44}R^{21}\sin(21A) + D_{45}R^{22}\cos(22A) + D_{46}R^{22}\sin(22A) + D_{47}R^{23}\cos(23A) + D_{48}R^{23}\sin(23A) + D_{49}R^{24}\cos(24A) + D_{50}R^{24}\sin(24A) + D_{51}R^{25}\cos(25A) + D_{52}R^{25}\sin(25A) + D_{53}R^{26}\cos(26A) + D_{54}R^{26}\sin(26A) + D_{55}R^{27}\cos(27A) + D_{56}R^{27}\sin(27A) + D_{57}R^{28}\cos(28A) + D_{58}R^{28}\sin(28A) + D_{59}R^{29}\cos(29A) + D_{60}R^{29}\sin(29A) + D_{61}R^{30}\cos(30A) + D_{62}R^{30}\sin(30A) + D_{63}R^{31}\cos(31A) + D_{64}R^{31}\sin(31A) + D_{65}R^{32}\cos(32A) + D_{66}R^{32}\sin(32A) + D_{67}R^{33}\cos(33A) + D_{68}R^{33}\sin(33A) + D_{69}R^{34}\cos(34A) + D_{70}R^{34}\sin(34A) + D_{71}R^{35}\cos(35A) + D_{72}R^{35}\sin(35A) + D_{73}R^{36}\cos(36A) + D_{74}R^{36}\sin(36A) + D_{75}R^{37}\cos(37A) + D_{76}R^{37}\sin(37A) + D_{77}R^{38}\cos(38A) + D_{78}R^{38}\sin(38A) + D_{79}R^{39}\cos(39A) + D_{80}R^{39}\sin(39A) + D_{81}R^{40}\cos(40A) + D_{82}R^{40}\sin(40A) + D_{83}R^{41}\cos(41A) + D_{84}R^{41}\sin(41A) + D_{85}R^{42}\cos(42A) + D_{86}R^{42}\sin(42A) + D_{87}R^{43}\cos(43A) + D_{88}R^{43}\sin(43A) + D_{89}R^{44}\cos(44A) + D_{90}R^{44}\sin(44A) + D_{91}R^{45}\cos(45A) + D_{92}R^{45}\sin(45A) + D_{93}R^{46}\cos(46A) + D_{94}R^{46}\sin(46A) + D_{95}R^{47}\cos(47A) + D_{96}R^{47}\sin(47A) + D_{97}R^{48}\cos(48A) + D_{98}R^{48}\sin(48A) + D_{99}R^{49}\cos(49A) + D_{100}R^{49}\sin(49A) + D_{101}R^{50}\cos(50A) + D_{102}R^{50}\sin(50A) + D_{103}R^{51}\cos(51A) + D_{104}R^{51}\sin(51A) + D_{105}R^{52}\cos(52A) + D_{106}R^{52}\sin(52A) + D_{107}R^{53}\cos(53A) + D_{108}R^{53}\sin(53A) + D_{109}R^{54}\cos(54A) + D_{110}R^{54}\sin(54A) + D_{111}R^{55}\cos(55A) + D_{112}R^{55}\sin(55A) + D_{113}R^{56}\cos(56A) + D_{114}R^{56}\sin(56A) + D_{115}R^{57}\cos(57A) + D_{116}R^{57}\sin(57A) + D_{117}R^{58}\cos(58A) + D_{118}R^{58}\sin(58A) + D_{119}R^{59}\cos(59A) + D_{120}R^{59}\sin(59A) + D_{121}R^{60}\cos(60A) + D_{122}R^{60}\sin(60A) + D_{123}R^{61}\cos(61A) + D_{124}R^{61}\sin(61A) + D_{125}R^{62}\cos(62A) + D_{126}R^{62}\sin(62A) + D_{127}R^{63}\cos(63A) + D_{128}R^{63}\sin(63A) + D_{129}R^{64}\cos(64A) + D_{130}R^{64}\sin(64A) + D_{131}R^{65}\cos(65A) + D_{132}R^{65}\sin(65A) + D_{133}R^{66}\cos(66A) + D_{134}R^{66}\sin(66A) + D_{135}R^{67}\cos(67A) + D_{136}R^{67}\sin(67A) + D_{137}R^{68}\cos(68A) + D_{138}R^{68}\sin(68A) + D_{139}R^{69}\cos(69A) + D_{140}R^{69}\sin(69A) + D_{141}R^{70}\cos(70A) + D_{142}R^{70}\sin(70A) + D_{143}R^{71}\cos(71A) + D_{144}R^{71}\sin(71A) + D_{145}R^{72}\cos(72A) + D_{146}R^{72}\sin(72A) + D_{147}R^{73}\cos(73A) + D_{148}R^{73}\sin(73A) + D_{149}R^{74}\cos(74A) + D_{150}R^{74}\sin(74A) + D_{151}R^{75}\cos(75A) + D_{152}R^{75}\sin(75A) + D_{153}R^{76}\cos(76A) + D_{154}R^{76}\sin(76A) + D_{155}R^{77}\cos(77A) + D_{156}R^{77}\sin(77A) + D_{157}R^{78}\cos(78A) + D_{158}R^{78}\sin(78A) + D_{159}R^{79}\cos(79A) + 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D_{200}R^{99}\sin(99A) + D_{201}R^{100}\cos(100A) + D_{202}R^{100}\sin(100A) + D_{203}R^{101}\cos(101A) + D_{204}R^{101}\sin(101A) + D_{205}R^{102}\cos(102A) + D_{206}R^{102}\sin(102A) + D_{207}R^{103}\cos(103A) + D_{208}R^{103}\sin(103A) + D_{209}R^{104}\cos(104A) + D_{210}R^{104}\sin(104A) + D_{211}R^{105}\cos(105A) + D_{212}R^{105}\sin(105A) + D_{213}R^{106}\cos(106A) + D_{214}R^{106}\sin(106A) + D_{215}R^{107}\cos(107A) + D_{216}R^{107}\sin(107A) + D_{217}R^{108}\cos(108A) + D_{218}R^{108}\sin(108A) + D_{219}R^{109}\cos(109A) + D_{220}R^{109}\sin(109A) + D_{221}R^{110}\cos(110A) + D_{222}R^{110}\sin(110A) + D_{223}R^{111}\cos(111A) + D_{224}R^{111}\sin(111A) + D_{225}R^{112}\cos(112A) + D_{226}R^{112}\sin(112A) + D_{227}R^{113}\cos(113A) + D_{228}R^{113}\sin(113A) + D_{229}R^{114}\cos(114A) + D_{230}R^{114}\sin(114A) + D_{231}R^{115}\cos(115A) + D_{232}R^{115}\sin(115A) + D_{233}R^{116}\cos(116A) + D_{234}R^{116}\sin(116A) + D_{235}R^{117}\cos(117A) + D_{236}R^{117}\sin(117A) + D_{237}R^{118}\cos(118A) + D_{238}R^{118}\sin(118A) + D_{239}R^{119}\cos(119A) + D_{240}R^{119}\sin(119A) + D_{241}R^{120}\cos(120A) + D_{242}R^{120}\sin(120A) + D_{243}R^{121}\cos(121A) + D_{244}R^{121}\sin(121A) + D_{245}R^{122}\cos(122A) + D_{246}R^{122}\sin(122A) + D_{247}R^{123}\cos(123A) + D_{248}R^{123}\sin(123A) + D_{249}R^{124}\cos(124A) + D_{250}R^{124}\sin(124A) + D_{251}R^{125}\cos(125A) + D_{252}R^{125}\sin(125A) + D_{253}R^{126}\cos(126A) + D_{254}R^{126}\sin(126A) + D_{255}R^{127}\cos(127A) + D_{256}R^{127}\sin(127A) + D_{257}R^{128}\cos(128A) + D_{258}R^{128}\sin(128A) + D_{259}R^{129}\cos(129A) + D_{260}R^{129}\sin(129A) + D_{261}R^{130}\cos(130A) + D_{262}R^{130}\sin(130A) + D_{263}R^{131}\cos(131A) + D_{264}R^{131}\sin(131A) + D_{265}R^{132}\cos(132A) + D_{266}R^{132}\sin(132A) + D_{267}R^{133}\cos(133A) + D_{268}R^{133}\sin(133A) + D_{269}R^{134}\cos(134A) + D_{270}R^{134}\sin(134A) + D_{271}R^{135}\cos(135A) + D_{272}R^{135}\sin(135A) + D_{273}R^{136}\cos(136A) + D_{274}R^{136}\sin(136A) + D_{275}R^{137}\cos(137A) + D_{276}R^{137}\sin(137A) + D_{277}R^{138}\cos(138A) + D_{278}R^{138}\sin(138A) + D_{279}R^{139}\cos(139A) + D_{280}R^{139}\sin(139A) + D_{281}R^{140}\cos(140A) + D_{282}R^{140}\sin(140A) + D_{283}R^{141}\cos(141A) + D_{284}R^{141}\sin(141A) + D_{285}R^{142}\cos(142A) + D_{286}R^{142}\sin(142A) + D_{287}R^{143}\cos(143A) + D_{288}R^{143}\sin(143A) + D_{289}R^{144}\cos(144A) + D_{290}R^{144}\sin(144A) + D_{291}R^{145}\cos(145A) + D_{292}R^{145}\sin(145A) + D_{293}R^{146}\cos(146A) + D_{294}R^{146}\sin(146A) + D_{295}R^{147}\cos(147A) + D_{296}R^{147}\sin(147A) + D_{297}R^{148}\cos(148A) + D_{298}R^{148}\sin(148A) + D_{299}R^{149}\cos(149A) + D_{300}R^{149}\sin(149A) + D_{301}R^{150}\cos(150A) + D_{302}R^{150}\sin(150A) + D_{303}R^{151}\cos(151A) + D_{304}R^{151}\sin(151A) + D_{305}R^{152}\cos(152A) + D_{306}R^{152}\sin(152A) + D_{307}R^{153}\cos(153A) + D_{308}R^{153}\sin(153A) + D_{309}R^{154}\cos(154A) + D_{310}R^{154}\sin(154A) + D_{311}R^{155}\cos(155A) + D_{312}R^{155}\sin(155A) + D_{313}R^{156}\cos(156A) + D_{314}R^{156}\sin(156A) + D_{315}R^{157}\cos(157A) + D_{316}R^{157}\sin(157A) + D_{317}R^{158}\cos(158A) + D_{318}R^{158}\sin(158A) + D_{319}R^{159}\cos(159A) + D_{320}R^{159}\sin(159A) + D_{321}R^{160}\cos(160A) + D_{322}R^{160}\sin(160A) + D_{323}R^{161}\cos(161A) + D_{324}R^{161}\sin(161A) + D_{325}R^{162}\cos(162A) + D_{326}R^{162}\sin(162A) + D_{327}R^{163}\cos(163A) + D_{328}R^{163}\sin(163A) + D_{329}R^{164}\cos(164A) + D_{330}R^{164}\sin(164A) + D_{331}R^{165}\cos(165A) + D_{332}R^{165}\sin(165A) + D_{333}R^{166}\cos(166A) + D_{334}R^{166}\sin(166A) + D_{335}R^{167}\cos(167A) + D_{336}R^{167}\sin(167A) + D_{337}R^{168}\cos(168A) + D_{338}R^{168}\sin(168A) + D_{339}R^{169}\cos(169A) + D_{340}R^{169}\sin(169A) + D_{341}R^{170}\cos(170A) + D_{342}R^{170}\sin(170A) + D_{343}R^{171}\cos(171A) + D_{344}R^{171}\sin(171A) + D_{345}R^{172}\cos(172A) + D_{346}R^{172}\sin(172A) + D_{347}R^{173}\cos(173A) + D_{348}R^{173}\sin(173A) + D_{349}R^{174}\cos(174A) + D_{350}R^{174}\sin(174A) + D_{351}R^{175}\cos(175A) + D_{352}R^{175}\sin(175A) + D_{353}R^{176}\cos(176A) + D_{354}R^{176}\sin(176A) + D_{355}R^{177}\cos(177A) + D_{356}R^{177}\sin(177A) + D_{357}R^{178}\cos(178A) + D_{358}R^{178}\sin(178A) + D_{359}R^{179}\cos(179A) + D_{360}R^{179}\sin(179A) + D_{361}R^{180}\cos(180A) + D_{362}R^{180}\sin(180A) + D_{363}R^{181}\cos(181A) + D_{364}R^{181}\sin(181A) + D_{365}R^{182}\cos(182A) + D_{366}R^{182}\sin(182A) + D_{367}R^{183}\cos(183A) + D_{368}R^{183}\sin(183A) + D_{369}R^{184}\cos(184A) + D_{370}R^{184}\sin(184A) + D_{371}R^{185}\cos(185A) + D_{372}R^{185}\sin(185A) + D_{373}R^{186}\cos(186A) + D_{374}R^{186}\sin(186A) + D_{375}R^{187}\cos(187A) + D_{376}R^{187}\sin(187A) + D_{377}R^{188}\cos(188A) + D_{378}R^{188}\sin(188A) + D_{379}R^{189}\cos(189A) + D_{380}R^{189}\sin(189A) + D_{381}R^{190}\cos(190A) + D_{382}R^{190}\sin(190A) + D_{383}R^{191}\cos(191A) + D_{384}R^{191}\sin(191A) + D_{385}R^{192}\cos(192A) + D_{386}R^{192}\sin(192A) + D_{387}R^{193}\cos(193A) + D_{388}R^{193}\sin(193A) + D_{389}R^{194}\cos(194A) + D_{390}R^{194}\sin(194A) + D_{391}R^{195}\cos(195A) + D_{392}R^{195}\sin(195A) + D_{393}R^{196}\cos(196A) + D_{394}R^{196}\sin(196A) + D_{395}R^{197}\cos(197A) + D_{396}R^{197}\sin(197A) + D_{397}R^{198}\cos(198A) + D_{398}R^{198}\sin(198A) + D_{399}R^{199}\cos(199A) + D_{400}R^{199}\sin(199A) + D_{401}R^{200}\cos(200A) + D_{402}R^{200}\sin(200A) + D_{403}R^{201}\cos(201A) + D_{404}R^{201}\sin(201A) + D_{405}R^{202}\cos(202A) + D_{406}R^{202}\sin(202A) + D_{407}R^{203}\cos(203A) + D_{408}R^{203}\sin(203A) + D_{409}R^{204}\cos(204A) + D_{410}R^{204}\sin(204A) + D_{411}R^{205}\cos(205A) + D_{412}R^{205}\sin(205A) + D_{413}R^{206}\cos(206A) + D_{414}R^{206}\sin(206A) + D_{415}R^{207}\cos(207A) + D_{416}R^{207}\sin(207A) + D_{417}R^{208}\cos(208A) + D_{418}R^{208}\sin(208A) + D_{419}R^{209}\cos(209A) + D_{420}R^{209}\sin(209A) + D_{421}R^{210}\cos(210A) + D_{422}R^{210}\sin(210A) + D_{423}R^{211}\cos(211A) + D_{424}R^{211}\sin(211A) + D_{425}R^{212}\cos(212A) + D_{426}R^{212}\sin(212A) + D_{427}R^{213}\cos(213A) + D_{428}R^{213}\sin(213A) + D_{429}R^{214}\cos(214A) + D_{430}R^{214}\sin(214A) + D_{431}R^{215}\cos(215A) + D_{432}R^{215}\sin(215A) + D_{433}R^{216}\cos(216A) + D_{434}R^{216}\sin(216A) + D_{435}R^{217}\cos(217A) + D_{436}R^{217}\sin(217A) + D_{437}R^{218}\cos(218A) + D_{438}R^{218}\sin(218A) + D_{439}R^{219}\cos(219A) + D_{440}R^{219}\sin(219A) + D_{441}R^{220}\cos(220A) + D_{442}R^{220}\sin(220A) + D_{443}R^{221}\cos(221A) + D_{444}R^{221}\sin(221A) + D_{445}R^{222}\cos(222A) + D_{446}R^{222}\sin(222A) + D_{447}R^{223}\cos(223A) + D_{448}R^{223}\sin(223A) + D_{449}R^{224}\cos(224A) + D_{450}R^{224}\sin(224A) + D_{451}R^{225}\cos(225A) + D_{452}R^{225}\sin(225A) + D_{453}R^{226}\cos(226A) + D_{454}R^{226}\sin(226A) + D_{455}R^{227}\cos(227A) + D_{456}R^{227}\sin(227A) + D_{457}R^{228}\cos(228A) + D_{458}R^{228}\sin(228A) + 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D_{533}R^{266}\cos(266A) + D_{534}R^{266}\sin(266A) + D_{535}R^{267}\cos(267A) + D_{536}R^{267}\sin(267A) + D_{537}R^{268}\cos(268A) + D_{538}R^{268}\sin(268A) + D_{539}R^{269}\cos(269A) + D_{540}R^{269}\sin(269A) + D_{541}R^{270}\cos(270A) + D_{542}R^{270}\sin(270A) + D_{543}R^{271}\cos(271A) + D_{544}R^{271}\sin(271A) + D_{545}R^{272}\cos(272A) + D_{546}R^{272}\sin(272A) + D_{547}R^{273}\cos(273A) + D_{548}R^{273}\sin(273A) + D_{549}R^{274}\cos(274A) + D_{550}R^{274}\sin(274A) + D_{551}R^{275}\cos(275A) + D_{552}R^{275}\sin(275A) + D_{553}R^{276}\cos(276A) + D_{554}R^{276}\sin(276A) + D_{555}R^{277}\cos(277A) + D_{556}R^{277}\sin(277A) + D_{557}R^{278}\cos(278A) + D_{558}R^{278}\sin(278A) + D_{559}R^{279}\cos(279A) + D_{560}R^{279}\sin(279A) + D_{561}R^{280}\cos(280A) + D_{562}R^{280}\sin(280A) + D_{563}R^{281}\cos(281A) + D_{564}R^{281}\sin(281A) + D_{565}R^{282}\cos(282A) + D_{566}R^{282}\sin(282A) + D_{567}R^{283}\cos(283A) + D_{568}R^{283}\sin(283A) + D_{569}R^{284}\cos(284A) + D_{570}R^{284}\sin(284A) + D_{571}R^{285}\cos(285A) + D_{572}R^{285}\sin(285A) + D_{573}R^{286}\cos(286A) + D_{574}R^{286}\sin(286A) + D_{575}R^{287}\cos(287A) + D_{576}R^{287}\sin(287A) + D_{577}R^{288}\$

[0099] Further, other known types of decentered prism members may be used as the decentered prism members 2L and 2R, which constitute the optical systems for the left and right eyes in the foregoing examples.

[0100] Next, image display apparatuses according to Examples 16 to 30 will be described as specific numerical examples of the present invention.

[0101] Fig. 16 is a diagram for describing the image display apparatus according to Example 16, in which: Fig. 16(a) is a horizontal sectional view (YZ-section) showing optical systems for two eyes; and Fig. 16(b) is a horizontal sectional view showing only the optical system for the right eye. Regarding the following Examples 17 to 28, horizontal sectional views of optical systems for two eyes, which are similar to Fig. 16 (a), are shown in Figs. 17 to 27.

[0102] In any of the examples, the optical systems have configurations that are symmetric with respect to the plane of symmetry between the two eyes as in the case of the above-described Examples 1 to 15. Therefore, only constituent parameters in the backward ray tracing of the optical system for the right eye as shown in Fig. 16(b) will be shown later. Regarding the constituent parameters in the backward ray tracing in Examples 16 to 28 (described later), as shown in Fig. 16(b), an axial principal ray (optical axis) O is defined by a light ray passing through the center of the exit pupil 4R of the optical system at right angles thereto and reaching the center of the image display device 3. In the backward ray tracing, the center of the pupil 4R is defined as the origin of decentered optical surfaces of a decentered optical system. A Z-axis is taken in the direction of the axial principal ray O, and the direction in which the Z-axis extends from the pupil 4R toward the final surface of the optical system (the first surface in the backward ray tracing: entrance surface; in Fig. 16(b), the fourth surface 24R) is defined as a positive direction of the Z-axis. A plane containing the Z-axis and the center of the image display device 3 is defined as a YZ-plane. An axis extending through the origin at right angles to the YZ-plane is defined as an X-axis, and the direction in which the X-axis extends from the obverse side toward the reverse side of the plane of the figure is defined as a positive direction of the X-axis. An axis that constitutes a right-handed orthogonal coordinate system in combination with the X- and Z-axes is defined as a Y-axis. In Fig. 16(b), this coordinate system is shown. Illustration of the coordinate system is omitted in Figs. 17 to 27, which show Examples 17 to 28.

[0103] In Examples 16 to 30, decentration of each surface is made in the YZ-plane, and the one and only plane of symmetry of each rotationally asymmetric free-form surface is the YZ-plane.

[0104] Regarding decentered surfaces, each surface is given displacements in the X-, Y- and Z-axis directions (X, Y and Z, respectively) of the vertex position of the surface from the origin of the above-described coordinate system, and tilt angles (degrees) of the center axis of the surface [the Z-axis of the above equation (a) in regard to free-form surfaces; the Z-axis of the following equation (d) in the case of aspherical surfaces] with respect to the X-, Y- and Z-axes (alpha, beta and gamma, respectively). In this case, the positive alpha and (beta mean counterclockwise rotation relative to the positive directions of the corresponding axes, and the positive gamma means clockwise rotation relative to the positive direction of the Z-axis.

[0105] Among optical functional surfaces constituting the optical system in each example, a specific surface and a surface subsequent thereto are given a surface separation when these surfaces form a coaxial optical system. In addition, the refractive index and Abbe's number of each medium are given according to the conventional method.

[0106] The configuration of each free-form surface used in the present invention is defined by the above equation (a). The Z-axis of the defining equation is the axis of the free-form surface.

[0107] Aspherical surfaces are rotationally symmetric aspherical surfaces given by the following equation: "(d)" $Z = \{ (C_2/R) [1 + \{1 + (1+K)Y^2/R^2\}^{1/2}] + AY^4 + BY^6 + CY^8 + DY^{10} + \dots$

[0108] In the above equation, Z is an optical axis (axial principal ray) for which the direction of travel of light is defined as a positive direction, and Y is taken in a direction perpendicular to the optical axis. R is a paraxial curvature radius, K is a conic constant, and A, B, C, D are 4th-, 6th-, 8th- and 10th-order aspherical coefficients, respectively. The Z-axis of this defining equation is the axis of the rotationally symmetric aspherical surface.

[0109] It should be noted that those terms concerning free-form surfaces and aspherical surfaces for which no data is shown are zero. The refractive index is expressed by the refractive index for the spectral d-line (wavelength: 587.56 nanometers). Lengths are given in millimeters.

[0110] In addition, other examples of defining equations for free-form surfaces include Zernike polynomials given by the above equation (b).

[0111] Although in the examples of the present invention the surface configuration is expressed by a free-form surface using the above equation (a), it should be noted that the same advantageous effect can be obtained by using the above equation (b) or (c), as a matter of course.

[0112] Referring back to Fig. 16(a), a major difference between Example 16 and Example 4 is in the optical path distributing prism 10. The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a third surface 14R as a transmitting surface for the right optical path and a third surface 14L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the side remote from the observer; and a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located on the sides of the fourth surfaces 14R and 14L remote from the observer. The fourth surface 14R as a transmitting surface for the right optical path and the fourth surface 14L as a transmitting surface for the left optical path are identical with the third surface 13L as a reflecting surface for the left optical path and the third surface 13R as a reflecting surface for the right optical path, respectively. The identical surfaces each serve as both a transmitting surface and a totally reflecting surface. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The fourth surfaces 14R and 14L and the second surfaces 12R and 12L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0113] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second

surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. Then, the reflected light is incident on the third surface 13R as a reflecting surface for the right optical path, which serves also as the transmitting surface 14L for the left optical path, and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0114] Example 17 shown in Fig. 17 is similar to Example 1 in Fig. 1 but different from Example 1 in the arrangement of the optical path distributing mirror 1 at the middle between the two eyes. In the case of this example, a reflecting surface 1R for the right optical path and a reflecting surface 1L for the left optical path, which have symmetric configurations with respect to the plane of symmetry between the two eyes, are formed from back-coated mirrors produced by coating the back surfaces of lenses 8R and 8L. The rest of Example 17 is the same as that in Example 1.

[0115] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes, first, enters the lens 8R for the right optical path, which constitutes the optical path distributing mirror 1, through the entrance surface 11L and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. It should be noted that no intermediate image is formed in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0116] Example 18 shown in Fig. 18 is similar to Example 4 in Fig. 4.

[0117] Example 19 shown in Fig. 19 is similar to Example 5 in Fig. 5.

[0118] Example 20 shown in Fig. 20 is similar to Example 6 in Fig. 6.

[0119] Fig. 21 shows Example 21. A major difference between Example 21 and Example 6 is in the optical path distributing prism 10. The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has seven surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are reflecting surfaces facing the first surface 11 and also facing the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are disposed at both sides of the first surface 11 on the observer side thereof; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are disposed on both sides between the third surfaces 13R and 13L and the second surfaces 12R and 12L, respectively. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R and 12L, the third surfaces 13R and 13L and the fourth surfaces 14R and 14L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0120] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. Then, the reflected light is incident on the third surface 13R and reflected thereby. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0121] Example 22 shown in Fig. 22 is similar to Example 21 in Fig. 21 but different from Example 21 in that ocular lenses 9R and 9L are placed between the exit surfaces 24R and 24L of the decentered prism members 2R and 2L for the right and left eyes, which constitute ocular optical systems, and the exit pupils 4R and 4L for the right and left eyes, respectively.

[0122] Example 23 shown in Fig. 23 is similar to Example 2 in Fig. 2.

[0123] Example 24 shown in Fig. 24 is similar to Example 2 in Fig. 2 but different therefrom in that the negative lens 5 is formed from a cemented lens.

[0124] Fig. 25 shows Example 25. A major difference between Example 25 and Example 1 is as follows. The optical path distributing mirror 1 at the middle between the two eyes has four reflecting surfaces, i.e. a reflecting surface 1R for the right optical path and a reflecting surface 1L for the left optical path, which have

symmetric configurations with respect to the plane of symmetry between the two eyes, and a second reflecting surface 1R' for the right optical path and a second reflecting surface 1L' for the left optical path, which face the reflecting surfaces 1R and 1L, respectively. The second reflecting surfaces 1R' and 1L' have configurations that are symmetric with respect to the plane of symmetry between the two eyes. Moreover, the image display device 3 is placed on the side of the optical path distributing mirror 1 remote from the observer.

[0125] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the reflecting surface 1R for the right optical path, which constitutes the optical path distributing mirror 1, and reflected by the reflecting surface 1R. Then, the light is incident on the second reflecting surface 1R' for the right optical path and reflected thereby so as to enter the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0126] Example 26 shown in Fig. 26 is similar to Example 11 in Fig. 11.

[0127] Example 27 shown in Fig. 27 is similar to Example 7 in Fig. 7. However, the second surfaces 22L and 22R and the fourth surfaces 24L and 24R of the decentered prism members 2L and 2R constituting the ocular optical systems for the right and left eyes are formed from the identical reflecting surfaces, respectively.

[0128] Example 28 shown in Fig. 28 is similar to Example 12 in Fig. 12.

[0129] Fig. 29 is a ray path diagram showing image display apparatus according to Examples 29 and 30 of the present invention. In Fig. 29, an image display device constituting the image display device is denoted by reference numeral 3. An exit pupil for the right eye is denoted by 4R, and an exit pupil for the left eye is denoted by 4L. A decentered prism member placed in front of the right eye as an optical system for the right eye is denoted by 2R, and a decentered prism member placed in front of the left eye as an optical system for the left eye is denoted by 2L. In addition, an optical path distributing prism formed from a decentered prism member, which is placed at the middle between the two eyes, is denoted by 10. The decentered prism members 2R, 2L and 10 are made of a transparent medium having a refractive index larger than 1. In the following description, surfaces stated to be reflecting surfaces are mirror surfaces formed by providing mirror coatings on the relevant surfaces of the decentered prism members except totally reflecting surfaces.

[0130] Examples 29 and 30 are arranged as shown in Fig. 29, which shows a horizontal section (YZ-section) thereof. First, the arrangement will be described in regard to the optical path for the right eye. The triangular prism-shaped optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to a plane 20 of symmetry between the two eyes (i.e. a plane passing through the center of a line segment connecting the respective centers of the exit pupil 4R for the right eye and the exit pupil 4L for the left eye at right angles to the line segment). The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof to function as totally reflecting surfaces; a transmitting surface 13L for the left optical path that is the identical with the second surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path that is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane 20 of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane 20 of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0131] The decentered prism member 2R, which constitutes an optical system for the right eye, and the decentered prism member 2L, which constitutes an optical system for the left eye, have the same configuration and are placed in symmetry with respect to the plane 20 of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L). The second surface 22R (22L) and the fourth surface 24R (24L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0132] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane 20 of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism and is incident on the second surface 22R at an incident angle not less than the critical angle, thereby being totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane 20 of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0133] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably

corrected for various aberrations, e.g. curvature of field and chromatic aberration.

[0134] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact.

[0135] Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0136] It is premised that an image display device 3 having wide viewing angle characteristics is used in the above-described optical system. Therefore, it is desirable to use a spontaneous light-emission type organic EL (see Fig. 40) for the image display device 3. When a transmission type LCD (liquid crystal display device) is used, it is desirable to insert a DOE (diffractive optical element) between the LCD and the backlight to thereby illuminate the LCD with ± 1 -st-order light, or to use an LCD with viewing angle characteristics widened by using such scattering film that the viewing angle is increased (the same is the case with Examples 1 to 30).

[0137] Incidentally, it is desirable that the angle α of reflection of display light at the second surfaces 12R and 12L of the optical path distributing prism 10 for distributing the display image of the image display device 3 to the optical path for the right eye and the optical path for the left eye, as shown in Fig. 30 (only the optical path for the right eye is shown in Fig. 30, for the sake of simplicity, because the optical path for the right eye and the optical path for the left eye are in plane-symmetric relation to each other in the image display apparatus according to the present invention), satisfy the following condition: "(1)" $33 \text{ DEG} \leq \alpha \leq 70 \text{ DEG}$

[0138] If α is smaller than the lower limit of this condition, i.e. 33 DEG , rays are not reflected by the second surfaces 12R and 12L but pass therethrough, thus failing, to form an image. If α exceeds the upper limit, i.e. 70 DEG , it is difficult for rays to travel along the above-described optical paths in the arrangement of this optical system. Consequently, the rays fail to form an image.

[0139] It is more desirable to satisfy the following condition: "(1-1)" $40 \text{ DEG} \leq \alpha \leq 60 \text{ DEG}$

[0140] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (1).

[0141] Next, it is desirable that the angle β formed between a plane 20 passing through the center of a line segment connecting the center of the exit pupil 4R for the right eye and the center of the exit pupil 4L for the left eye at right angles to the line segment (the plane of symmetry between the two eyes) and a tangent plane 15 to the second surface 12R of the optical path distributing prism 10 at a point where the optical axis of the optical path for the right eye is incident on the second surface 12R and the angle β formed between the plane 20 and a tangent plane to the second surface 12L of the optical path distributing prism 10 at a point where the optical axis of the optical path for the left eye is incident on the second surface 12L satisfy the following condition: "(2)" $13 \text{ DEG} \leq \beta \leq 24 \text{ DEG}$

[0142] If β is smaller than the lower limit of this condition, i.e. 13 DEG , some of the reflected rays do not pass through the third surface 13R but are undesirably reflected thereby, or rays are not reflected by the second surface 22R of the decentered prism member 2R but pass therethrough, undesirably. Consequently, it is difficult for rays to travel along the above-described optical paths, and the rays fail to form an image. If β exceeds the upper limit, i.e. 24 DEG , some rays are not reflected by the second surface 12R but pass therethrough, undesirably. Consequently, it is difficult for rays to travel along the above-described optical paths, and the rays fail to form an image.

[0143] It is more desirable to satisfy the following condition: "(2-1)" $15 \text{ DEG} \leq \beta \leq 22 \text{ DEG}$

[0144] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (2).

[0145] It is even more desirable to satisfy the following condition: "(2-2)" $17 \text{ DEG} \leq \beta \leq 20 \text{ DEG}$

[0146] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (2).

[0147] Next, let us assume that, in backward ray tracing from the pupil side, the distance between the intersection of the ray passing through the center of the exit pupil 4R for the right eye at the maximum field angle on the right-hand side and the fourth surface 24R of the decentered prism member 2R for the right eye and the intersection of the ray passing through the center of the exit pupil 4L for the left eye at the maximum field angle on the left-hand side and the fourth surface 24L of the decentered prism member 2L for the left eye is a width L , as shown in Fig. 31, and the distance between the point closest to the left and right exit pupils among points at which bundles of rays passing through the centers of the left and right exit pupils within the overall field angle pass through or are reflected by the fourth surface 24R of the decentered prism member 2R for the right eye ER or the fourth surface 24L of the decentered prism member 2L for the left eye EL and the display surface of the image display device 3 in a direction perpendicular to the display surface is a depth D . In this case, it is desirable that the ratio of the depth D to the width L , i.e. D/L , satisfy the following condition: "(3)" $0.3 \leq D/L \leq 0.5$

[0148] If D/L is smaller than the lower limit, i.e. 0.3 , a wide field angle cannot be obtained. Consequently, the image field becomes unfavorably small in size. If D/L exceeds the upper limit, i.e. 0.5 , the depth assumes a large value, and the optical system becomes unfavorably large in size.

[0149] It is more desirable to satisfy the following condition: "(3-1)" $0.35 \leq D/L \leq 0.45$

[0150] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (3).

[0151] Regarding Examples 29 and 30, horizontal sectional views illustrating only optical systems for the right eye in these examples are shown in Figs. 32 and 33 because the optical system and optical path for the right eye and the optical system and optical path for the left eye are in plane-symmetric relation to each other as stated above. Regarding the optical system for the left eye, it is only necessary to place the surfaces of the optical system for the left eye in symmetric relation to the optical system for the right eye with respect to the plane 20 of symmetry between the two eyes (Fig. 29).

[0152] Constituent parameters in the backward ray tracing of the optical systems for the right eye in the above-described Examples 16 to 30 will be shown below. The observation field angles in these examples when arranged in the form of a viewing optical system are as follows: in Examples 16 to 21 and 23 to 28, the horizontal half field angle is 10 DEG, and the vertical half field angle is 7.5 DEG; in Example 22, the horizontal half field angle is 12 DEG, and the vertical half field angle is 9.1 DEG; in Example 29, the horizontal half field angle is 7 DEG, and the vertical half field angle is 5.26 DEG; and in Example 30, the horizontal half field angle is 7.5 DEG, and the vertical half field angle is 5.64 DEG. In Examples 16 to 28, the size of the image display device is 8.9x6.7 mm. In Example 29, the image display device size is 8.94x6.71 mm. In Example 30, the image display device size is 8.94x6.71 mm. In all Examples 16 to 30, the pupil diameter is 4 mm. It should be noted that when arranged in the form of a viewing optical system, Example 29 is equivalent to an optical system with a focal length of 36 mm, and Example 30 is equivalent to an optical system with a focal length of 34 mm.

[0153] It should be noted that in the tables below, "FFS" denotes a free-form surface, and "ASS" denotes an aspherical surface, and further "RE" denotes a reflecting surface. <tb><TABLE> Columns=6 <tb>Title: Example 16 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS 1 &cir& <SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS 1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& (RE)<SEP><SEP>(6) <SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP> INFINITY <SEP><SEP>(7) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -61.00 K 0.0000 A -2.8485x10<-6> B 8.9070x10<-9>

FFS1 &cir& C4 -1.2212x10<-2> C6 -1.2499x10<-2> C8 -7.2115x10<-6> C10 3.6893x10<-5> C11 -2.8593x10<-6> C13 -3.0073 x 10<-6> C15 -3.4462x10<-6> C17 -1.6344x10<-9> C19 -4.1364x10<-8> C21 -2.0345x10<-8>

FFS2 &cir& C4 1.0330x10<-2> C6 -2.2053x10<-2> C8 -8.5243x10<-5>

C10 -1.3497x10<-3> C11 1.1148x10<-4> C13 -2.6040x10<-4> C15 3.9230x10<-4>

F F S3 &cir& C4 -8.5360 x 10<-3> C8 -8. 8071 x 10<-3> C87.1801 x 10<-5> C10 7.6086x10<-5> C11 6.3213x10<-7> C13 8.2333x10<-6> C15 1.9455x10<-6>

FFS4 &cir& C4 8.5360x10<-3> C6 8.8071x10<-3> C8 -7.1801x10<-5> C10 -7.6086x10<-5> C11 -6.3213x10<-7> C13 -8.2333x10<-6> C15 -1.9455x10<-6>

FFS5 &cir& C4 1.2329x10<-2> C6 6.7124x10<-3> C8 -3.9501x10<-5> C10 -1.3809x10<-4> C11 -1.6628x10<-6> C13 3.6302x10<-6> C15 -3.8832x10<-6>

Displacement and tilt(1) X 0.00 Y 9.84 Z 32.73 alpha -0.83 beta 0.00 gamma 0.00

Displacement and tilt(2)

X 0.00 Y -0.48 Z 39.28 alpha -30.61 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 16.17 Z 37.03 alpha 35.52 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.39 Z 46.79 alpha -91.71 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 44.61 Z 46.79 alpha -88.29 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 22.62 Z 55.56 alpha 136.79 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 33.76 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 29.64 alpha -180.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 17 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS3 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(6)

*ASS1 &cir& R -95.45 K 0.0000 A -6.5740x10<-8> B 1.3849x10<-9>

FFS1 &cir& C4 -1.0306x10<-2> C6 -1.0412x10<-2> C8 2.0096x10<-5> C10 2.8787x10<-5> C11 -7.7967x10<-7> C13 -2.3996x10<-6> C15 -2.6208 x 10<-6> C17 -6.0108x10<-8> C19 1.1907 x 10<-8> C21 1.4876x10<-8>

FFS2 &cir& C4 -7.5538x10<-3> C6 6.696x10<-4> C8 1.3858 x 10<-3> C10 2.0287x10<-3> C11 8.0303x10<-5> C13 -1.5350x10<-4> C15 -6.5070x10<-5>

FFS3 &cir& C 4 -7.6923x10<-2> C5 -9.3217x10<-3> C6 3.8760x10<-3> C10 -9.4736x10<-4> C11 -7.2844x10<-4> C13 6.5675x10<-4> C15 -4.9359x10<-5>

FFS4 &cir& C4 -1.1587x10<-2> C6 1.1772x10<-2> C8 1.0849x10<-3> C10 -1.8206 x10<-4> C11 -5.4651 x 10<-4> C13 1.7195 x 10<-4> C15 -1.3202x10<-5>

Displacement and tilt(1) X 0.00 Y 9.05 Z 39.11 alpha 10.70 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.24 Z 48.07 alpha -21.35 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 19.03 Z 43.57 alpha 92.98 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 35.65 Z 58.02 alpha -145.94 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 39.28 Z 61.80 alpha -147.29 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 38.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 18 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
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<tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5
&cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

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F F S1 &cir& C4 -1.3402x10<-2> C6 -1.1018x10<-2> C8 2.9828x10<-6> C10 -4.6829x10<-6> C11 -
2.4079x10<-6> C13 -3.1115x10<-6> C15 -2.2505x10<-6> C17 1.0452x10<-7> C 19 1.1084x10<-7> C21
2.6833x10<-8>

FFS2 &cir& C 4 -1.9489x10<-2> C6 -3.8803x10<-3> C8 4.8522x10<-3> C10 4.8858x10<-3> C11
1.6575x10<-4> C13 -7.7300x10<-4> C15 -6.0291x10<-4>

FFS3 &cir& C4 -8.6443x10<-2> C6-3.9460x10<-2> C8 8.0248x10<-3> C10 9.1640 x 10<-3> C11 -
6.2318x10<-5> C13 1.4493 x 10<-3> C15 1.6706x10<-3>

FFS4 &cir& C4 1.9984x10<-2> C6 1.7719x10<-2> C8 2.2720x10<-4> C10 2.2345x10<-4> C11
6.1407x10<-6> C13 2.3412x10<-5> C15 -1.4916x10<-6>

FFS5 &cir& C4 -1.0029x10<-2> C6 4.6836 x 10<-3>

Displacement and tilt(1) X 0.00 Y 12.74 Z 36.00 alpha 2.52 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.37 Z 45.03 alpha -28.87 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 20.71 Z 40.51 alpha 74.60 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 22.61 Z 41.95 alpha -113.38 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 38.54 Z 52.07 alpha -144.30 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 36.77 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 30.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 19 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
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&cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2
<tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5
&cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 371.46 K 0.0000 A -8.4688x10<-7> B 2.9089x10<-10>

FFS1 &cir& C 4 -6.3820x10<-3> C6 -8.9287x10<-3> C8 -7.5189x10<-5> C10 -2.7485x10<-6> C11 -
5.1745x10<-6> C13 -6.0033x10<-7> C15 2.8823x10<-6> C17 3.2184x10<-7> C19 8.6382 x 10<-8> C21 -
1.5488x10<-8>

FFS2 &cir& C4 -4.0226x10<-2> C6 -3.3297x10<-2> C8 2.4201x10<-3> C10 6.0781x10<-3> C11
7.4789x10<-4> C13 -3.2635x10<-4> C 15 2.1572x10<-4>

FFS3 &cir& C4 -2.0127x10<-2> C6 -1.4009x10<-2> C8 -1.3093x10<-3> C10 -1.0545x10<-4> C11 -
2.3099x10<-4> C13 -2.8818x10<-5> C15 -1.4532x10<-6>

FFS4 &cir& C4 2.0127x10<-2> C61.4009x10<-2> C8 1.3093x10<-3> C10 1.0645x10<-4> C11 2.3099x10<-
4> C13 2.8818x10<-5> C15 1.4532x10<-6>

FFS5 &cir& C4 2.3952x10<-1> C6 6.3371x10<-4>

Displacement and tilt(1) X 0.00 Y 20.12 Z 35.02 alpha 6.83 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.52 Z 47.68 alpha -27.07 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 27.52 Z 37.59 alpha 76.08 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 29.00 Z 40.96 alpha -118.18 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 35.00 Z 40.96 alpha -61.82 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 50.73 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 58.00 alpha -180.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 20 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
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&cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2
<tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5
&cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS6 &cir& <SEP><SEP>(7)
<tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -78.87 K 0.0000 A 6.3888x10<-6> B -6.7614x10<-9>

FFS1 &cir& C4 -1.3820x10<-2> C6 -1.2744x10<-2> C8 -5.9146x10<-5> C10 -8.6079x10<-5> C11 -1.5009x10<-6> C13 -3.9389x10<-6> C15 -3.9837x10<-6> C17 9.5456x10<-8> C19 2.5646x10<-7> C21 8.4257x10<-8>

FFS2 &cir& C4 -4.8112x10<-2> C6 2.2437x10<-2> C8 1.2629x10<-2> C10 -1.4147x10<-3> C11 1.1201x10<-3> C13 -4.2802x10<-3> C15 -1.8265x10<-5>

FFS3 &cir& C4 -2.4894x10<-2> C6 1.7719x10<-3> C8 1.3030x10<-2> C10 8.7223x10<-3> C11 -2.5693x10<-3> C13 2.0937x10<-3> C15 -1.7955x10<-4>

FFS4 &cir& C4 1.4510x10<-2> C6 1.4974x10<-2> C8 6.3447x10<-5> C10 -3.3021x10<-5> C11 6.7340x10<-6> C13 1.3268x10<-5> C15 5.6476x10<-6>

FFS5 &cir& C4 -5.0177x10<-3> C6 4.2398x10<-3> C11 1.3297x10<-5> C13 1.7182x10<-5> C15 7.8122x10<-6>

FFS6 &cir& C4 6.6144x10<-2> C6 3.1372x10<-2> C11 5.4070x10<-4> C13 -2.1336x10<-4> C15 -4.3706x10<-4>

Displacement and tilt(1) X 0.00 Y 13.06 Z 30.44 alpha 4.48 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.13 Z 38.51 alpha -29.74 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 17.85 Z 32.43 alpha 74.33 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.17 Z 33.07 alpha -102.30 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 44.66 Z 43.01 alpha -133.87 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 30.30 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 48.57 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 53.57 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
 <tb><TABLE> Columns=6 <tb>Title: Example 21 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop)<SEP><SEP>(1)<SEP><SEP>% <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(3)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(4) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& (RE)<SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS6 &cir& <SEP><SEP>(8) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(9)

ASS1 &cir& R -93.13 K 0.0000 A -7.3153x10<-6> B 1.0465x10<-8>

FFS1 &cir& C4 -1.2530x10<-2> C6 -1.0935x10<-2> C8 4.3572x10<-5> C10 5.6790x10<-5> C11 -4.6759x10<-6> C13 5.7024x10<-6> C15 -2.5865x10<-6> C17 5.1708x10<-8> C19 4.7739x10<-8> C21 4.8274x10<-8>

FFS2 &cir& C4 2.1276x10<-2> C6 -1.3001x10<-2> C8 1.2698x10<-2> C10 -4.0940x10<-3> C11 6.8259x10<-4> C13 -1.1193x10<-3> C15 -4.9525x10<-5>

FFS3 &cir& C4 -7.7818x10<-2> C6 -1.3978x10<-2> C8 8.2943x10<-3> C10 -3.6125x10<-3> C11 -2.1473x10<-3> C13 1.6422 x 10<-3> C15 2.1472x10<-4>

FFS4 &cir& C4 1.7708x10<-2> C6 9.8479x10<-3> C8 4.2747x10<-5> C10 1.4710x10<-5> C11 6.0476x10<-6> C13 9.5455x10<-6> C15 7.9647x10<-6>

FFS5 &cir& C4 -3.2083x10<-3> C6 -1.1682x10<-2> C8 -3.8379x10<-4> C10 -4.7983x10<-4> C11 3.2203x10<-5> C13 2.4146x10<-5> C15 1.5623x10<-5>

FFS6 &cir& C4 -1.2690x10<-2> C6 1.2046x10<-2>

Displacement and tilt(1) X 0.00 Y 0.00 Z 0.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 11.12 Z 31.05 alpha 6.41 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y -0.11 Z 39.90 alpha -26.24 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.37 Z 34.98 alpha 52.37 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 19.70 Z 35.09 alpha -124.03 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 41.67 Z 44.93 alpha -137.82 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 36.67 Z 30.00 alpha -176.69 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 48.79 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 32.00 Z 51.01 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
 <tb><TABLE> Columns=6 <tb>Title: Example 22 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop)<SEP><SEP>(1) <tb><SEP>2<SEP> INFINITY <SEP><SEP>(2)<SEP>1.4924<SEP>107.9 <tb><SEP>3<SEP>ASS1 &cir& <SEP><SEP>(3)<SEP><SEP>4<SEP>ASS2 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS1 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>ASS2 &cir& (RE)<SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS2 &cir& <SEP><SEP>(6) <tb><SEP>8<SEP>FFS3 &cir& <SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS4 &cir& (RE)<SEP><SEP>(8)

<SEP>1.5254<SEP>56.2 <tb><SEP>10<SEP>FFS5 &cir& (RE)<SEP><SEP>(9)<SEP>1.5254<SEP>56.2
<tb><SEP>11<SEP>FFS6 &cir& <SEP><SEP>(10) <tb><SEP>Image plane<SEP> INFINITY
<SEP><SEP>(11)

ASS1 &cir& R -31.17 K 0.0000 A -2.3392x10<-6> B 1.4417x10<-8>

ASS2 &cir& R -104.32 K 0.0000 A -1.1160x10<-5> B 1.3866x10<-8>

FFS1 &cir& C4 -1.1076x10<-2> C6 -9.7026x10<-3> C8 1.2453x10<-4> C10 8.6331x10<-5>

FFS2 &cir& C4 -2.6908x10<-2> C6 -2.2030x10<-2> C8 3.0544x10<-3> C10 -2.0443x10<-3>

FFS3 &cir& C4 -4.7273x10<-2> C6 -2.9318x10<-2> C8 4.8533x10<-4> C10 -2.1511x10<-3>

FFS4 &cir& C4 1.3337x10<-2> C6 7.7917x10<-3> C8 5.2903x10<-6> C10 3.2236x10<-5>

FFS5 &cir& C4 -7.4443x10<-3> C6 -1.1004x10<-2> C8 -3.4435 x 10<-4> C10 -2.7416x10<-4>

FFS6 &cir& C4 8.1792x10<-3> C6 7.4722x10<-3>

Displacement and tilt(1) X 0.00 Y 0.00 Z 0.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.00 Z 25.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 0.00 Z 29.43 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 10.49 Z 30.94 alpha 6.19 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y -0.10 Z 40.19 alpha -24.76 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 18.51 Z 35.34 alpha 55.35 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 19.05 Z 35.60 alpha -111.46 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 41.39 Z 45.63 alpha -142.01 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 38.56 Z 29.81 alpha 177.05 beta 0.00 gamma 0.00

Displacement and tilt(10) X 0.00 Y 32.00 Z 49.26 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(11) X 0.00 Y 32.00 Z 51.37 alpha 0.00 13 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 23 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
<tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2
&cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& (RE)<SEP><SEP>(4)
<tb><SEP>7<SEP>9.36<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>ASS2 &cir&
<SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R -112.57 K 0.0000 A 1.2804x10<-7> B 1.9023x10<-9>

ASS2 &cir& R 17.18 K 0.0000 A -1.1585x10<-4> B 4.5485x10<-6>

FFS1 &cir& C4 -1.0758x10<-2> C6 -1.0721x10<-2> C8 7.6154x10<-5> C10 -1.9106x10<-5> C11
4.9749x10<-6> C13 -5.3415x10<-6> C15 -2.8610x10<-6> C17 1.3623x10<-7> C19 2.9234x10<-8> C21 -
5.0012x10<-9>

FFS2 &cir& C4 -4.2973x10<-2> C6 3.8451x10<-2> C8 3.6896x10<-3> C10 5.7252x10<-3> C11
1.4826x10<-4> C13 -1.1264x10<-3> C15 4.7888x10<-4>

FFS3 &cir& C4 2.0862x10<-2> C6 1.8162x10<-2> C8 1.4811x10<-4> C10 -2.1971x10<-5> C11
1.3347x10<-5> C13 2.3775x10<-5> C15 7.6542x10<-6>

Displacement and tilt(1) X 0.00 Y 12.30 Z 38.14 alpha -1.09 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.33 Z 45.00 alpha -31.99 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 19.10 Z 42.18 alpha 78.03 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 39.78 Z 60.30 alpha -147.16 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 32.00 Z 40.06 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 37.55 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 31.96 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 24 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
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&cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& (RE)<SEP><SEP>(4)
<tb><SEP>7<SEP>10.00<SEP><SEP>(5)<SEP>1.7400<SEP>45.0 <tb><SEP>8<SEP>-
30.00<SEP><SEP>(6)<SEP>1.4875<SEP>70.2 <tb><SEP>9<SEP>20.00<SEP><SEP>(7)
<tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -755.72 K 0.0000 A -3.0223x10<-6> B 3.6982x10<-9>

FFS1 &cir& C4 -1.3291x10<-2> C6 -9.1362x10<-3> C8 1.3010x10<-5> C10 -4.7998x10<-5> C11
3.8631x10<-8> C13 1.2388x10<-6> C15 -1.7387x10<-6> C17 4.1889x10<-7> C19 3.3450x10<-8> C21
1.5434x10<-8>

FFS2 &cir C4 -4.9441x10<-2> C6 5.0481x10<-2> C8 -1.8555x10<-3> C10 1.1867x10<-3> C11 -1.0276x10<-3> C13 2.6209x10<-3> C15 1.5600x10<-4>

FFS3 &cir C4 2.1838x10<-2> C6 2.0822x10<-2> C8 1.5599x10<-4> C10 2.2274x10<-5> C11 1.7287x10<-5> C13 3.1039x10<-5> C15 1.7347x10<-5>

Displacement and tilt(1) X 0.00 Y 15.24 Z 38.77 alpha 2.68 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.01 Z 47.98 alpha -29.39 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 22.36 Z 42.21 alpha 83.11 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 38.88 Z 54.45 alpha -145.16 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 32.00 Z 34.24 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 33.17 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 30.48 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 28.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 25 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object<SEP> INFINITY <SEP>-1000.00 <tb><SEP>plane <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir & (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir & (RE)<SEP><SEP>(3)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir & <SEP><SEP>(4) <tb><SEP>6<SEP>FFS3 &cir & (RE)<SEP><SEP>(5) <tb><SEP>7<SEP>FFS4 &cir & (RE)<SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir R -142.30 K 0.0000 A -7.9459x10<-6> B 4.5193x10<-9>

FFS1 &cir C4 -1.5782x10<-2> C6 -9.2595x10<-3> C8 8.4720x10<-5> C10 4.5249x10<-5> C11 1.0602x10<-5> C13 -8.7497x10<-5> C15 -4.4525 x 10<-6> C17 -5.8969x10<-8> C19 1.8760 x 10<-7> C21 1.2837x10<-7>

FFS2 &cir C4 -4.8446x10<-2> C6 -8.3829x10<-3>

FFS3 &cir C4 1.6543x10<-2> C6 9.5400x10<-3> C8 -1.0953x10<-4> C10 -1.8587x10<-5> C11 5.3062 x10<-6> C13 7.9992 x 10<-6> C15 5.7818x10<-6>

FFS4 &cir C4 -4.2215x10<-3> C6 1.0692x10<-2> C8 -3.6896x10<-4> C10 -2.5259x10<-4> C11 5.9277x10<-6> C13 -1.3516x10<-5> C15 -7.8520x10<-6>

Displacement and tilt(1) X 0.00 Y 11.67 Z 32.96 alpha -1.41 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.45 Z 40.56 alpha -30.45 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 18.56 Z 37.77 alpha 33.95 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 43.39 Z 48.16 alpha -135.03 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 36.28 Z 31.09 alpha 6.39 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 55.72 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 26 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>FFS1 &cir & <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS2 &cir & (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>FFS3 &cir & <SEP><SEP>(3) <tb><SEP>5<SEP>FFS4 &cir & <SEP><SEP>(4) <SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>FFS5 &cir & (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS6 &cir & <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

FFS1 &cir C4 -6.2629x10<-3> C6 3.3796x10<-4> C8 3.9666x10<-4> C10 -1.2581x10<-4> C11 2.6158x10<-6> C13 3.2906x10<-5> C15 1.4501x10<-6>

FFS2 &cir C4 -1.3276x10<-2> C6 -9.4693x10<-3> C8 -8.4725x10<-5> C10 -1.3499x10<-4> C11 -2.9102x10<-6> C13 -2.0112x10<-6> C15 -2.4589x10<-6> C17 -4.4244x10<-9> C19 -4.8328x10<-8> C21 -1.8143x10<-8>

FFS3 &cir C4 -2.1469x10<-2> C6 -3.3694x10<-2> C8 -1.6179x10<-3> C10 -3.2678x10<-3> C11 -7.9899x10<-5> C13 -1.7505x10<-4> C15 -3.5647x10<-4>

FFS4 &cir C4 -1.1648x10<-1> C6 -4.0332x10<-2> C8 -1.1348x10<-3> C10 1.9930x10<-3> C11 8.3579x10<-4> C13 8.0595x10<-4> C15 9.9925x10<-4>

FFS5 &cir C4 1.9541x10<-2> C6 1.6255x10<-2> C8 -1.0516x10<-5> C10 -5.5991x10<-5> C11 4.5526x10<-6> C13 1.2743 x 10<-5> C15 3.8394x10<-6>

FFS6 &cir C4 1.9172x10<-2> C6 3.2175x10<-2> C11 9.6401x10<-5> C13 -2.6951x10<-5> C15 -1.6440x10<-4>

Displacement and tilt(1) X 0.00 Y 0.00 Z 32.45 alpha -13.66 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -1.36 Z 48.79 alpha -33.83 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 12.70 Z 41.59 alpha -50.46 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.62 Z 39.02 alpha -65.04 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 42.00 Z 30.00 alpha -44.81 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 45.53 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 53.23 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
 <tb><TABLE> Columns=6 <tb>Title: Example 27 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
 Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
 Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object t plane<SEP> INFINITY <SEP>
 1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
 <SEP>1.5254<SEP>56.2 2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS1
 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>FFS2 &cir& <SEP><SEP>(3)
 <tb><SEP>7<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS4 &cir&
 (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS5 &cir& <SEP><SEP>(6)
 <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R -109.37 K 0.0000 A 2.7422x10<-5> B -4.1869x10<-8>

FFS1 &cir& C4 -1.1126x10<-2> C6 -1.0227x10<-2> C8 -6.0588x10<-5> C10 -3.0318x10<-5> C11
 7.9055x10<-6> C13 1.1105x10<-5> C15 1.0604x10<-6> C17 2.8597x10<-7> C19 1.5498x10<-7> C21
 1.4283x10<-7>

FFS2 &cir& C4 3.6878x10<-2> C6 3.5702x10<-2> C8 -2.0106x10<-2> C10 -9.8201x10<-3> C11
 2.1010x10<-3> C13 -1.9983x10<-3> C15 9.8827x10<-4>

FFS3 &cir& C4 -1.0254x10<-1> C6 -2.5575x10<-2> C8 -2.0239x10<-2> C10 -5.8721x10<-3> C11
 1.0962x10<-3> C13 -3.3381x10<-3> C15 4.7815x10<-4>

FFS4 &cir& C4 2.3287x10<-2> C6 1.8127x10<-2> C8 -4.0703x10<-4> C10 -2.4676x10<-4> C11
 1.9470x10<-5> C13 3.1178x10<-5> C15 -3.0929x10<-7>

FFS5 &cir& C4 -1.9980x10<-2> C6 -1.9644x10<-2> C11 1.8913x10<-4> C13 4.0095x10<-4> C15
 5.1524x10<-4>

Displacement and tilt(1) X 0.00 Y 6.56 Z 32.12 alpha -2.57 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.19 Z 38.74 alpha -23.54 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 20.79 Z 39.32 alpha -71.99 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 21.54 Z 38.60 alpha -84.73 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 36.81 Z 30.00 alpha -35.69 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 44.11 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 50.34 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
 <tb><TABLE> Columns=6 <tb>Title: Example 28 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
 Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
 Col 5: Refractive index <tb>Head Col 6: Abbe' S No. <tb><SEP>Object plane<SEP> INFINITY <SEP>
 1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>FFS1 &cir& <SEP><SEP>(1)
 <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS2 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
 <tb><SEP>4<SEP>FFS3 &cir& (RE)<SEP><SEP>(3)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS4
 &cir& <SEP><SEP>(4) <tb><SEP>6<SEP>FFS5 &cir& <SEP><SEP>(5)<SEP>1.5254<SEP>56.2
 <tb><SEP>7<SEP>FFS6 &cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS7
 &cir& (RE)<SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS8 &cir& <SEP><SEP>(8)
 <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(9)

FFS1 &cir& C4 -8.4040x10<-3> C6 -8.5948x10<-3>

FFS2 &cir& C4 -4.8109x10<-3> C6 -3.4151x10<-3> C8 7.6983x10<-6> C10 5.9643x10<-6>

FFS3 &cir& C4 8.5504x10<-4> C6 2.0899x10<-3> C8 3.9710x10<-6> C10 1.2427x10<-5>

FFS4 &cir& C4 -4.1338x10<-3> C6 4.6863x10<-3>

FFS5 &cir& C4 1.8948x10<-2> C6 7.8112x10<-3>

FFS6 &cir& C4 -2.9136x10<-3> C6 -2.6792x10<-3>

FFS7 &cir& C4 1.0066x10<-2> C6 1.0913x10<-2>

FFS8 &cir& C4 -2.2044x10<-2> C6 -1.6909x10<-2>

Displacement and tilt(1) X 0.00 Y 0.00 Z 30.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 7.73 Z 66.05 alpha 18.69 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y -17.85 Z 38.62 alpha 46.96 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 20.71 Z 58.27 alpha 70.85 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 21.56 Z 58.79 alpha 72.18 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 41.10 Z 68.55 alpha 46.38 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 28.64 Z 46.33 alpha 17.45 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.02 Z 71.98 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 32.00 Z 76.97 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
 <tb><TABLE> Columns=6 <tb>Title: Example 29 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
 Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
 Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>
 1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)

<SEP>1.5254<SEP>56.2 <lb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
<lb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <lb><SEP>5<SEP>FFS2
&cir& <SEP><SEP>(3) <lb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2
<lb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <lb><SEP>8<SEP>FFS5
&cir& <SEP><SEP>(6) <lb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 1285.39 K 0.0000 A 6.4599x10<-7> B -3.7861x10<-10>

FFS1 &cir& C4 -3.6795x10<-3> C6 -2.1319x10<-3> C8 -5.8405x10<-5> C10 -6.5664x10<-5> C11 8.
2431x10<-7> C13 1.4603x10<-6> C15 1.4571x10<-6> C17 -5.6374x10<-8> C19 -3.7292x10<-8> C21 -
4.3730x10<-8>

FFS2 &cir& C4 -3.1489x10<-4> C6 5.2538x10<-3> C8 1.2817x10<-3> C10 1.2156x10<-3> C11
5.1327x10<-6> C13 -1.0362x10<-5> C15 4.7618x10<-5>

F F S3 &cir& C4 -2.2969 x 10<-3> C6 -4.7767x10<-4> C8 3.1569x10<-4> C10 1.9939x10<-4> C11
4.1969x10<-7> C13 1.3660x10<-5> C15 4.6817x10<-6>

FFS4 &cir& C4 2.2969x10<-3> C6 4.7767x10<-4> C8 -3.1569x10<-4> C10 -1.9939x10<-4> C11 -
4.1969x10<-7> C13 -1.3660x10<-5> C15 -4.6817x10<-8>

FFS5 &cir& C4 2.5793x10<-2> C6 -4.2457x10<-3> C11 -4.8745x10<-4> C13 -1.7443x10<-4> C15 -
3.6717x10<-5>

Displacement and tilt(1) X 0.00 Y 10.19 Z 29.40 alpha 7.35 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -3.29 Z 36.33 alpha -25.35 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 24.99 Z 36.53 alpha 82.49 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 18.12 Z 7.32 alpha -18.71 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 18.12 Z -7.32 alpha 18.71 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 24.00 Z 0.00 alpha 90.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 0.00 Z 1.73 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>
<tb><TABLE> Columns=6 <tb>Title: Example 30 <lb> <tb>Head Col 1: Surface No. <tb>Head Col 2:
Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head
Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-
1000.00 <lb><SEP>1<SEP> INFINITY (Stop) <lb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)
<SEP>1.5254<SEP>56.2 <lb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2
<lb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <lb><SEP>5<SEP>FFS2
&cir& <SEP><SEP>(3) <lb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2
<lb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <lb><SEP>8<SEP>FFS5
&cir& <SEP><SEP>(6) <lb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 368.58 K 0.0000 A 7.6841x10<-7> B -3.6756x10<-11>

FFS1 &cir& C4 -2.7896x10<-3> C6 -1.4546x10<-3> C8 -5.7608x10<-5> C10 -9.2334x10<-5> C11
5.8163x10<-7> C13 3.5074x10<-6> C15 2.2152x10<-6> C17 -1.6054 x 10<-7> C19 -1.1334x10<-7> C21 -
1.0782x10<-7>

FFS2 &cir& C4 3.3609x10<-4> C6 8.4179x10<-2> C8 -3.1419x10<-5> C10 3.1128x10<-3> C11
3.4030x10<-5> C13 -1.1634x10<-4> C15 3.9570x10<-5>

FFS3 &cir& C4 -3.7622x10<-3> C6 -3.6532x10<-3> C8 1.5526x10<-4> C10 -5.4887x10<-6> C11 -
7.4035x10<-6> C13 1.0763x10<-5> C15 -6.6288 x 10<-7>

FFS4 &cir& C4 3.7622x10<-3> C6 3.6532x10<-3> C8 -1.5526x10<-4> C10 5.4887x10<-6> C11
7.4035x10<-6> C13 -1.0763x10<-5> C15 6.6288x10<-7>

FFS5 &cir& C4 2.8169x10<-2> C6 4.5388x10<-4> C11 -4.5848x10<-4> C13 -8.7689 x10<-5> C15 -8.8053
x10<-6>

Displacement and tilt(1) X 0.00 Y 17.47 Z 30.07 alpha -1.32 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.39 Z 38.40 alpha -28.76 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 30.09 Z 31.35 alpha 36.81 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.88 Z 6.67 alpha -15.86 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 19.88 Z -6.67 alpha 15.86 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 29.00 Z 0.00 alpha 90.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 0.00 Z 1.82 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>

[0154] Figs. 34, 35, 36, 37 and 38 are aberrational diagrams showing lateral aberrations in the above-
described Examples 16, 20, 22, 29 and 30. In the diagrams showing lateral aberrations, the numerals in the
parentheses denote (horizontal field angle, vertical field angle), and lateral aberrations at the field angles
are shown.

[0155] It should be noted that the values of the conditions (4) and (6), which will be described later, in the
above-described Examples 16 to 28 are as follows: <tb><TABLE> Columns=3 <lb> <tb>Head Col 1:
<tb>Head Col 2: Condition (4) <th>1(θ) <tb>Head Col 3: Condition (6) SIGMA D1(mm) <tb>Example
16<SEP>22.5<SEP>119.4 <tb>Example 17<SEP>41.0<SEP>57.7 <tb>Example 18<SEP>37.2<SEP>62.5
<tb>Example 19<SEP>22.0<SEP>33.4 <tb>Example 20<SEP>26.1<SEP>99.4 <tb>Example
21<SEP>18.8<SEP>92.7 <tb>Example 22<SEP>25.6<SEP>95.7 <tb>Example 23<SEP>41.2<SEP>58.3
<tb>Example 24<SEP>35.6<SEP>50.1 <tb>Example 25<SEP>22.7<SEP>70.4 <tb>Example
26<SEP>20.4<SEP>78.5 <tb>Example 27<SEP>43.8<SEP>56.2 <tb>Example 28<SEP>31.2<SEP>117.5
<tb></TABLE>

[0156] Next, the values concerning the conditions (1) to (3) in the above-described Examples 29 and 30 are as follows:

Columns=4	Head Col 1: <tb>Head Col 2: <tb>Head Col 3: Example 29
Head Col 4: Example 30	Condition (1)<SEP> alpha <SEP>43 DEG </a</=54 DEG <SEP>43 DEG </a</=58 DEG <tb>Condition (2)<SEP> beta <SEP>19 DEG <SEP>18 DEG <tb>Condition (3)<SEP> D<SEP>27.5 mm<SEP>31 mm <tb><SEP>L<SEP>72 mm<SEP>72 mm <tb><SEP>D/L<SEP>0.38<SEP>0.43 <tb></table>

[0157] It should be noted that the free-form surfaces in the above-described Examples 16 to 30 may be replaced with spherical surfaces including plane surfaces, aspherical surfaces, anamorphic surfaces, or anamorphic aspherical surfaces.

[0158] Regarding the optical system of the image display apparatus according to the present invention as stated above, when a ray passing through the center of the image displayed by the image display device 3 and further passing through the center of a right-hand pupil 4R formed by the ocular prism 2R for the right eye is defined as a right-hand optical axis, and a ray passing through the center of the image displayed by the image display device 3 and further passing through the center of a left-hand pupil 4L formed by the ocular prism 2L for the left eye is defined as a left-hand optical axis, it is desirable to satisfy the following condition: "(4)" $10 \text{ DEG} < \theta_1 < 60 \text{ DEG}$ where θ_1 is the absolute value of the angle formed between each of the right-hand optical axis and the left-hand optical axis, which enter the ocular prism 2R for the right eye and the ocular prism 2L for the left eye from the optical path distributing mirror 1 or the optical path distributing prism 10, and the display surface of the image display device 3.

[0159] The condition (4) limits the angle formed between the axial principal ray entering the ocular prisms 2R and 2L from the optical path distributing means, which comprises the optical path distributing mirror 1 or the optical path distributing prism 10, and the image display device 3.

[0160] If θ_1 is not larger than the lower limit of the above condition (4), i.e. 10 DEG , the axial principal ray entering the ocular prisms from the optical path distributing means undesirably forms an optical path approximately parallel to the image display device. Consequently, it becomes difficult to ensure the left and right optical paths. Accordingly, it becomes necessary to use a half-mirror in order to distribute the optical path from a single image display device, e.g. an LCD, to the left and right ocular prisms. The use of a half-mirror results in an unfavorably dark image. If θ_1 is not smaller than the upper limit of the condition (4), i.e. 60 DEG , it is necessary to tilt each ocular prism to a considerable extent or to increase the size of the prism itself. Consequently, it becomes impossible to attain a compact and lightweight optical system.

[0161] It is more desirable for the above condition to be the following condition (5): "(5)" $15 \text{ DEG} < \theta_1 < 50 \text{ DEG}$

[0162] If the angle θ_1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while ensuring the left and right optical paths.

[0163] Further, when the distance from the image display device 3 to each of the entrance surface 21R of the ocular prism 2R for the right eye and the entrance surface 21L of the ocular prism 2L for the left eye along the optical axis is denoted by SIGMA D1, it is desirable to satisfy the following condition: "(6)" $20 \text{ mm} < \text{SIGMA D1} < 150 \text{ mm}$

[0164] The above condition (6) is a condition for attaining a reduction in size of the apparatus, which defines the optical path length of the axial principal ray from the image display device 3 to each of the ocular prisms 2R and 2L.

[0165] If SIGMA D1 is not larger than the lower limit of the above condition (6), i.e. 20 mm , the power of each surface of the optical path distributing means becomes extremely strong. Consequently, it becomes impossible to favorably correct decentration aberrations, particularly decentration comatic aberration. In addition, the angle between the image display device 3 and the rays (principal ray tilt angle) becomes extremely large, which is unfavorable. If SIGMA D1 is not smaller than the upper limit of the condition (6), i.e. 150 mm , the optical path distributing means becomes large in size and projects to a considerable extent in comparison to the ocular prisms, unfavorably.

[0166] It is more desirable for the above condition to be the following condition (7): "(7)" $30 \text{ mm} < \text{SIGMA D1} < 130 \text{ mm}$

[0167] If SIGMA D1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while maintaining the favorable performance.

[0168] It is even more desirable for the above condition to be the following condition (8): "(8)" $45 \text{ mm} < \text{ED1} < 120 \text{ mm}$

[0169] If SIGMA D1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while maintaining the favorable performance.

[0170] In the above-described optical system of the image display apparatus according to the present invention, it is possible to perform see-through observation of the outside world by bonding, as shown for example in Fig. 39, compensating prisms 16L and 16R to the reflecting surfaces 23L and 23R (in the case of Fig. 26, the reflecting surfaces 22L and 22R; in the case of Fig. 27, 22L, 22R, 24R and 24R; and in the case of Fig. 28, 23L and 23R) of the decentered prism members 2L and 2R for the left and right eyes on the outside-world sides thereof (on the sides thereof remote from the observer's face) or placing the compensating prisms 16L and 16R at a slight distance from the reflecting surfaces 23L and 23R as half-mirror surfaces for compensating for bending of the optical paths and further forming the outside world-side surfaces 17L and 17R of the compensating prisms 16L and 16R so that the surfaces 17L and 17R have approximately the same configurations as those of the observer's face-side transmitting surfaces 24L and 24R, respectively (in the case of Fig. 26, the transmitting surfaces 23L and 23R; in the case of Fig. 27, 25L and 25R; and in the case of Fig. 28, 24L and 24R) of the decentered prism members 2L and 2R for the left and right eyes, thereby allowing light from the outside world to pass approximately in straight lines. In this case, superimposing function or see-through function can be added by placing means for changing the transmittance of light from the outside world, e.g. a liquid crystal shutter, on the outside world side of the compensating prisms 16L and 16R.

[0171] In the present invention, a transmission type or reflection type LCD (liquid crystal display device) can be used as the image display device 3, as stated above. However, the use of a self-emission type panel makes it possible to simplify the structure and hence possible to construct a lightweight image display apparatus. The use of an LCD as the image display device 3 involves the problem that an illuminating light source, e.g. a backlight, is needed, and the problem that an LCD invariably needs a polarizer, and only a half of illuminating light can be used for display.

[0172] Therefore, it is desirable to use a self-emission type panel (display). Examples of self-emission panels include OLEDs (Organic Light Emitting Diodes), LEDs (Light Emitting Diodes), and an EL (Electroluminescence) panel having a structure such as that illustrated in Fig. 40.

[0173] Fig. 40 shows the structure of an organic EL comprising three layers. An organic EL layer comprising three layers, i.e. a hole injection layer, an organic EL layer, and an electron injection layer, is sandwiched between pixel electrodes provided on an Si substrate and having a switching element placed for each pixel and an ITO film provided on the lower surface of a glass substrate as a common electrode. When a voltage is applied between the ITO film and the pixel electrodes by the action of the switching elements, holes are injected into the organic EL layer from the hole injection layer and electrons are injected into the organic EL layer from the electron injection layer. The holes and the electrons recombine in the organic EL layer, causing the portions of the organic EL layer corresponding to the pixels to emit light. Thus, the desired image is displayed.

[0174] The advantage of the use of such a light-emission type display in the image display apparatus lies in its excellent viewing angle characteristics. In particular, in a head-mounted image display apparatus (HMD) designed for observation with two eyes, the pupils of the optical systems and the observer's pupils may be displaced with respect to each other owing to a difference in interpupillary distance among observers or displacement of the HMD body. In order to prevent the image for observation from darkening even when the observer's pupils are displaced, it is important to make the pupils of the optical systems free from aberrations over a wide range. Even if the optical systems are designed so that the pupils are widened, when the pupils are displaced, the observer is placed under conditions where he or she views the image display device obliquely through the ocular optical systems. In general, image display devices using LCD are inferior in viewing angle characteristics when viewed obliquely. That is, it is possible to view only an image for observation that is reduced in contrast or undesirably tone-reversed. Accordingly, the brightness and contrast of the image field undesirably vary according to the fitting position of the HMD, and it is difficult to view the image with stable image quality. With a light-emission type image display device, such problems are unlikely to occur, and it is therefore favorable for use as an image display device for an HMD.

[0175] Incidentally, it is possible to form a stationary or portable image display apparatus by preparing and supporting one set of image display apparatus according to the present invention arranged as stated above. Fig. 41 shows the image display apparatus. In Fig. 41, reference numeral 31 denotes a display apparatus body unit, which is fixed by a support member through the observer's head so that the display apparatus body unit 31 is held in front of both the observer's eyes. The support member has a pair of front frames 32 (left and right) each joined at one end thereof to the display apparatus body unit 31. The left and right front frames 32 extend from the observer's temples to the upper portions of his/her ears, respectively. A pair of rear frames 33 (left and right) are joined to the other ends of the front frames 32, respectively, and extend over the side portions of the observer's head. Alternatively, the support member further has a top frame 34 joined at both ends thereof to the other ends of the left and right rear frames 33, respectively, so that the top frame 34 supports the top of the observer's head.

[0176] A rear plate 35 is joined to one front frame 32 near the joint to the rear frame 33. The rear plate 35 is formed from an elastic member, e.g. a metal leaf spring. A rear cover 36, which constitutes a part of the support member, is joined to the rear plate 35 so that the rear cover 36 can support the apparatus at a position behind the observer's ear in a region extending from the back part of the head to the base of the neck. A speaker 39 is mounted inside the rear plate 35 or the rear cover 36 at a position corresponding to the observer's ear.

[0177] A cable 41 for transmitting external image and sound signals is led out from the display apparatus body unit 31. The cable 41 extends through the top frame 34, the rear frames 33, the front frames 32 and the rear plate 35 and projects to the outside from the rear end of the rear plate 35 or the rear cover 36. The cable 41 is connected to a video-replaying unit 40. It should be noted that reference numeral 40a in the figure denotes a switch and volume control part of the video-replaying unit 40.

[0178] The cable 41 may have a jack and plug arrangement attached to the distal end thereof so that the cable 41 can be connected to an existing video deck or the like. The cable 41 may also be connected to a TV signal-receiving tuner so as to enable the user to enjoy watching TV. Alternatively, the cable 41 may be connected to a computer to receive computer graphic images or message images or the like from the computer. To eliminate the bothersome cord, the apparatus may be arranged to receive external radio signals through an antenna connected thereto.

INDUSTRIAL APPLICABILITY

[0179] As will be clear from the foregoing description, it is possible according to the present invention to provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and in which an optical path distributing mirror or an optical path distributing prism placed at the middle between the two eyes facilitates the correction of various aberrations. In addition, it is possible to obtain an illuminating arrangement which is the most suitable for observation of a single panel with two eyes and which can be used without the need to switch the display image for the left and right.

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IMAGE DISPLAY

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Claims of corresponding document: EP 1186933 (A1)

1. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing mirror for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing mirror, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing mirror, said optical path distributing mirror having a mirror surface placed to face said image display device to reflect a display light beam emanating from said image display device so as to distribute the display light beam to said ocular prism for the right eye and said prism for the left eye, said mirror surface having a rotationally asymmetric curved surface configuration that corrects decentration aberrations, said ocular prism for the right eye having a first surface through which the light beam of the optical path for the right eye reflected by said optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism, said ocular prism for the left eye having a first surface through which the light beam of the optical path for the left eye reflected by said optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism, wherein at least the second surface of said ocular prism for the right eye, which is a reflecting surface, and the second surface of said ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.
2. An image display apparatus according to claim 1, wherein the rotationally asymmetric curved surface configuration of said optical path distributing mirror is a free-form surface having only one plane of symmetry.
3. An image display apparatus according to claim 2, wherein the free-form surface of said optical path distributing mirror has said only one plane of symmetry in a plane (YZ-plane) connecting a center of the image displayed by said image display device and a center of a right-hand pupil formed by said ocular prism for the right eye and further a center of a left-hand pupil formed by said ocular prism for the left eye.
4. An image display apparatus according to any one of claims 1 to 3, wherein said image display device is placed between said optical path distributing mirror and said observer in a longitudinal direction (Z-direction) and between said ocular prism for the right eye and said ocular prism for the left eye in a lateral direction (Y-direction).
5. An image display apparatus according to any one of claims 1 to 3, wherein a negative lens that gives a negative power to a light beam is placed between said image display device and said optical path distributing mirror.
6. An image display apparatus according to any one of claims 1 to 3, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing mirror and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing mirror and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism.
7. An image display apparatus according to any one of claims 1 to 3, wherein said first surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein said first surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.
8. An image display apparatus according to claim 7, wherein the rotationally asymmetric curved surface configuration of said first surface of said ocular prism for the right eye is a free-form surface having only one plane of symmetry, and wherein the rotationally asymmetric curved surface configuration of said first surface of said ocular prism for the left eye is a free-form surface having only one plane of symmetry.
9. An image display apparatus according to claim 8, wherein when a light ray passing through a center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the right eye is defined as an optical axis, the free-form surface of said first surface of said ocular prism for the right eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism, and wherein when a light ray passing through the center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the left eye is defined as an optical axis, the free-form surface of said first surface of said ocular prism for the left eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism.
10. An image display apparatus according to any one of claims 1 to 3, wherein said third surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein said third surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.
11. An image display apparatus according to claim 10, wherein the rotationally asymmetric curved surface configuration of said third surface of said ocular prism for the right eye is a free-form surface having only one plane of symmetry, and wherein the rotationally asymmetric curved surface configuration of said third surface of said ocular prism for the left eye is a free-form surface having only one plane of symmetry.
12. An image display apparatus according to claim 11, wherein when a light ray passing through a center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the right eye is defined as an optical axis, the free-form surface of said third surface of said ocular prism for the right eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism, and wherein when a light ray passing

through the center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the left eye is defined as an optical axis, the free-form surface of said third surface of said ocular prism for the left eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism.

13. An image display apparatus according to any one of claims 1 to 3, wherein said third surface of said ocular prism for the right eye is a rotationally symmetric aspherical surface, and wherein said third surface of said ocular prism for the left eye is a rotationally symmetric aspherical surface.

14. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second-first surface which reflects said optical path for the right eye entering through said first surface, a second-second surface which reflects said optical path for the left eye entering through said first surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface and said second-second surface have a curved surface configuration that gives a power to a light beam to form a relay image for the right eye from the image displayed by said image display device in said optical path for the right eye and to form a relay image for the left eye from the image displayed by said image display device in said optical path for the left eye, and said second-first surface and said second-second surface have a same surface configuration, said ocular prism for the right eye having a first surface through which the light beam of the optical path for the right eye exiting from said third-first surface of said optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism, said ocular prism for the left eye having a first surface through which the light beam of the optical path for the left eye exiting from said third-second surface of said optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism, wherein at least said second surface of said ocular prism for the right eye, which is a reflecting surface, and said second surface of said ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

15. An image display apparatus according to claim 14, wherein the third-first surface and third-second surface of said optical path distributing prism are curved surfaces of a same configuration.

16. An image display apparatus according to claim 14 or 15, wherein the first surface, second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other, and wherein the second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

17. An image display apparatus according to claim 15, wherein the curved surface configuration of the third-first surface and third-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

18. An image display apparatus according to claim 15, wherein the curved surface configuration of each of the second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

19. An image display apparatus according to any one of claims 15 to 18, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions facing each other across a medium, and then said third-first surface and said third-second surface are located, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

20. An image display apparatus according to any one of claims 15 to 18, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said third-first surface and said third-second surface are disposed at right and left positions facing each other across a medium, and then said second-first surface and said second-second surface are located, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

21. An image display apparatus according to claim 14, wherein a single surface is used as both said second-first surface and third-second surface of said optical path distributing prism, and a single surface is used as both said second-second surface and third-first surface of said optical path distributing prism, wherein said optical path for the right eye is made incident on the surface used as both said second-first surface and said third-second surface at an angle larger than a total reflection critical angle to reflect the light beam of the optical path for the right eye within the prism by total reflection, and said optical path for the right eye is made incident on the surface used as both said second-second surface and said third-first surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the right eye to exit from the prism, wherein said optical path for the left eye is made incident on the surface used as both the second-second surface and the third-first surface at an angle larger than the total reflection critical angle to reflect the light beam of the optical path for the left eye within the prism by total reflection, and said optical path for the left eye is made incident on the surface used as both the second-first surface and the third-second surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the left eye to exit from the prism, and wherein the surface used as both said second-first surface and third-second surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and the surface used as both said second-second surface and third-first surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

22. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a fourth surface with a curved surface configuration that reflects light beams of right and left images entering through the first surface toward the second-first surface and the second-second surface, respectively, wherein the first surface, second-first surface, second-second surface, third-first surface, third-second surface and fourth surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other.

23. An image display apparatus according to claim 22, wherein the curved surface configuration of the fourth surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

24. An image display apparatus according to claim 23, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions facing each other across a medium, and then said third-first surface and said third-second surface are located, said fourth surface being disposed at a position facing said first surface across the medium, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

25. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a fourth-first surface which reflects the optical path for the right eye entering through the first surface toward the second-first surface, and a fourth-second surface which reflects the optical path for the left eye entering through the first surface toward the second-second surface, wherein the first surface, second-first surface, second-second surface, third-first surface, third-second surface, fourth-first surface and fourth-second surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other.

26. An image display apparatus according to claim 25, wherein the fourth-first surface and fourth-second surface of said optical path distributing prism are curved surfaces of a same configuration.

27. An image display apparatus according to claim 26, wherein the curved surface configuration of the fourth-first surface and fourth-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

28. An image display apparatus according to claim 27, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions, respectively, facing each other across a medium, and then said third-second surface and said third-first surface are disposed at left and right positions, respectively, facing each other across the medium, and then the fourth-first surface and the fourth-second surface are disposed adjacently to each other at respective positions facing said first surface across the medium.

29. An image display apparatus according to any one of claims 14 to 28, wherein said first surface of said optical path distributing prism has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

30. An image display apparatus according to any one of claims 14 to 18, wherein the rotationally asymmetric curved surface of said optical path distributing prism is a free-form surface having only one plane of symmetry.

31. An image display apparatus according to claim 30, wherein the free-form surface of said optical path distributing prism has said only one plane of symmetry in a plane (YZ-plane) connecting a center of the image displayed by said image display device and a center of a pupil.

32. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism.

33. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said second surface, and the light beam reflected from said second surface passes through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said second surface, and the light beam reflected from said second surface passes through said third surface to exit from the prism.

34. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye has a fourth surface which reflects a light beam within the prism, said ocular prism for the right eye being arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said fourth surface, and the light beam reflected from said fourth surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and further the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye has a fourth surface which reflects a light beam within the prism, said ocular prism for the left eye being arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said fourth surface, and the light beam reflected from said fourth surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and further the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism.

prism.

35. An image display apparatus according to claim 34, wherein the fourth surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the fourth surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

36. An image display apparatus according to any one of claims 14 to 18, wherein the first surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the first surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

37. An image display apparatus according to any one of claims 14 to 18, wherein the second surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the second surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

38. An image display apparatus according to any one of claims 14 to 18, wherein the third surface of said ocular prism for the right eye is a rotationally symmetric aspherical surface, and wherein said third surface of said ocular prism for the left eye is a rotationally symmetric aspherical surface.

39. An image display apparatus according to any one of claims 14 to 18, wherein the third surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the third surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

40. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a positive power as a whole so that said relay image for the right eye is formed at a position closer to the right eye of the observer than said third-first surface on the optical path and said relay image for the left eye is formed at a position closer to the left eye of the observer than said third-second surface on the optical path.

41. An image display apparatus according to claim 40, wherein said optical path distributing prism forms said relay image for the right eye at a position between said third-first surface and the first surface of said ocular prism for the right eye and further forms said relay image for the left eye at a position between said third-second surface and the first surface of said ocular prism for the left eye.

42. An image display apparatus according to any one of claims 14 to 18, wherein an angle α of reflection of display light of the optical path for the right eye from the second-first surface of said optical path distributing prism and an angle α of reflection of display light of the optical path for the left eye from the second-second surface of said optical path distributing prism satisfy the following condition: "(1)" $33 \text{ DEG} \leq \alpha \leq 70 \text{ DEG}$

43. An image display apparatus according to any one of claims 14 to 18, wherein an angle β formed between a plane passing through a center of a line segment connecting a center of an exit pupil for the right eye and a center of an exit pupil for the left eye at right angles to the line segment and a tangent plane to the second-first surface of said optical path distributing prism at a point where the optical axis of the optical path for the right eye is incident on said second-first surface and an angle β formed between the plane passing through the center of the line segment connecting the center of the exit pupil for the right eye and the center of the exit pupil for the left eye at right angles to the line segment and a tangent plane to the second-second surface of said optical path distributing prism at a point where the optical axis of the optical path for the left eye is incident on said second-second surface satisfy the following condition: "(2)" $13 \text{ DEG} \leq \beta \leq 24 \text{ DEG}$

44. An image display apparatus according to any one of claims 14 to 18, wherein, in backward ray tracing from a pupil side, a distance between an intersection of a ray passing through a center of an exit pupil for the right eye at a maximum field angle on a right-hand side and the third surface of said ocular prism for the right eye and an intersection of a ray passing through a center of an exit pupil for the left eye at a maximum field angle on a left-hand side and the third surface of said ocular prism for the left eye is defined as a width L, and a distance between a point closest to the left and right exit pupils among points at which bundles of rays passing through the centers of the left and right exit pupils within an overall field angle pass through or are reflected by the third surface of said ocular prism for the right eye or the third surface of said ocular prism for the left eye and a display surface of said image display device in a direction perpendicular to the display surface is defined as a depth D, wherein a ratio of the depth D to the width L, i.e. D/L , satisfies the following condition: "(3)" $0.3 \leq D/L \leq 0.5$

45. An image display apparatus according to any one of claims 14 to 18, wherein the second surface of said ocular prism for the right eye is a semitransparent reflecting surface, and a see-through prism for the right eye is placed outside said second surface, and wherein the second surface of said ocular prism for the left eye is a semitransparent reflecting surface, and a see-through prism for the left eye is placed outside said second surface.

46. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second-first surface which reflects said optical path for the right eye entering through said first surface, a second-second surface which reflects said optical path for the left eye entering through said first surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface, said second-second surface, said third-first surface and said third-second surface have a curved surface configuration that gives a power to a light beam, and said second-first surface and said second-second surface have a same surface configuration and said third-first surface and said third-second surface have a same surface configuration, said image display device being a reflection type image display device that displays an image by reflecting a light beam from a light source, wherein both said second-first surface and second-second surface of said optical path distributing prism are either semitransparent reflecting surfaces or partially-transmitting and partially-reflecting surfaces, and wherein an illuminating light source for forming the optical path for the left eye is disposed at a position on a side of said second-first surface remote from a prism medium, and an illuminating light source for forming the optical path for the right eye is disposed at a position on a side of said second-second surface remote from the prism medium.

47. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a fourth surface placed to face said first surface across a medium so as to reflect light beams of right and left images entering through said first surface in different directions, thereby distributing the light beams to the optical path for the right eye and the optical path for the left eye, a second-first surface which reflects said optical path for the right eye reflected from said fourth surface, a second-second surface which reflects said optical path for the left eye reflected from said fourth surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface, said second-second surface, said third-first surface, said third-second surface and said fourth surface have a curved surface configuration that gives a power to a light beam, and said second-first surface and said second-second surface have a same surface configuration and said third-first surface and said third-second surface have a same surface configuration, said image display device being a reflection type image display device that displays an image by reflecting a light beam from a light source, wherein said fourth surface of said optical path distributing prism is either a semitransparent reflecting surface or a partially-transmitting and partially-reflecting surface, and wherein an illuminating light source for forming the optical path for the left eye and an illuminating light source for forming the optical path for the right eye are disposed at respective positions on a side of said fourth surface remote from the prism medium.

48. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second surface wherein said optical path for the right eye is made incident on an optical surface at an angle larger than a total reflection critical angle to reflect a light beam of the optical path for the right eye within the prism by total reflection and said optical path for the left eye is made incident on the optical surface at an angle smaller than the total reflection critical angle to allow a light beam of the optical path for the left eye to exit from the prism, and a third surface wherein said optical path for the left eye is made incident on an optical surface at an angle larger than a total reflection critical angle to reflect the light beam of the optical path for the left eye within the prism by total reflection and said optical path for the right eye is made incident on the optical surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the right eye to exit from the prism, wherein an optical element for display is placed between said image display device and said first surface, said optical path distributing prism being arranged so that said second surface and said third surface are curved surfaces of a same configuration that gives a power to a light beam, and said second surface and said third surface are placed to face each other across a prism medium, said image display device being a transmission type image display device that displays an image by transmitting a light beam from a light source, wherein an illuminating light source for forming the optical path for the left eye and an illuminating light source for forming the optical path for the right eye are disposed at respective positions on a side of said image display device remote from said optical element for display.

49. An image display apparatus according to claim 48, wherein said optical element for display is a Fresnel lens.

50. An image display apparatus according to claim 46, wherein both said second-first surface and second-second surface of said optical path distributing prism are formed from half-mirror coatings that divide transmission and reflection in terms of intensity.

51. An image display apparatus according to claim 46, wherein both said second-first surface and second-second surface of said optical path distributing prism are formed from mirror coatings each having transmitting holes provided in a reflecting mirror surface.

52. An image display apparatus according to claim 47, wherein the fourth surface of said optical path distributing prism is formed from a half-mirror coating that divides transmission and reflection in terms of intensity.

53. An image display apparatus according to claim 47, wherein the fourth surface of said optical path distributing prism is formed from a mirror coating having transmitting holes provided in a reflecting mirror surface.

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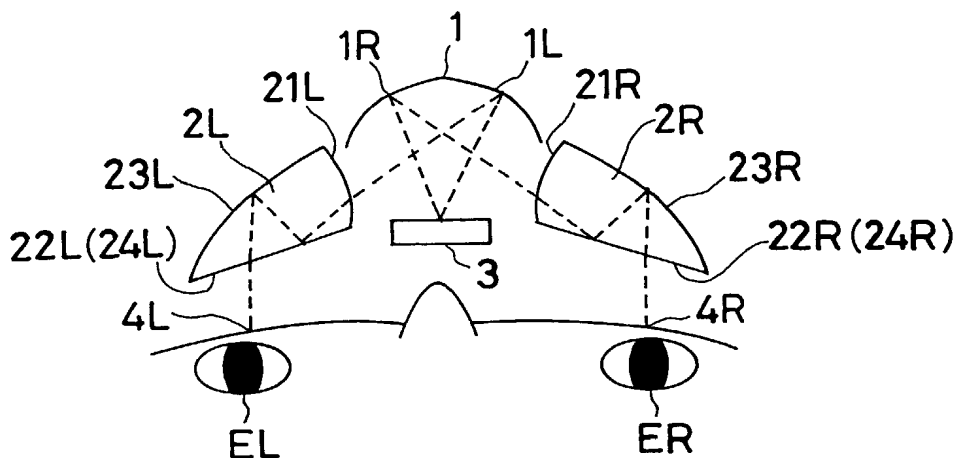
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(54) Title: IMAGE DISPLAY

(54) 発明の名称: 画像表示装置



(57) **Abstract:** An image display such as a head-mounted image display for allowing the user to view with both user's eyes an image displayed on one image display element by directing the image to both user's eyes without providing any half-silvered mirror. The image display comprises an optical path branching mirror (1) for distributing the image on one display element (10) to a right-eye optical path and a left-eye optical path, a right-eye ocular prism (2R) on the left side, and a left-eye ocular prism (2L) on the left side. Along the right-eye optical path, the display light from the display element (3) is reflected from the reflecting surface (1R) of the optical path branching mirror (1), passed through a first surface (21R) of a decentered prism (2R), made to enter the prism, total-reflected from a second surface (22R), back-reflected from a third surface (23R), made to exit from the prism through a fourth surface (24R) which the second surface (22R) serves as, directed to an exit pupil (4R) for the right eye, and projected to the right eye to form a magnified image of the image on the display element (3). As for the left-eye optical path, the display light travels similarly.

[続葉有]



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(57) 要約:

本発明は、1つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察できる頭部装着式画像表示装置等の画像表示装置に関し、1枚の表示素子(10)の画像を右眼用光路と左眼用光路とに振分ける光路振分けミラー(1)と、その右側の右眼用接眼プリズム(2R)と、その左側の左眼用接眼プリズム(2L)とを有し、右眼用の光路においては、表示素子(3)からの表示光は、光路振分けミラー(1)の反射面(1R)で反射され、偏心プリズム体(2R)の第1面(21R)を透過してプリズム内に入射し、第2面(22R)で全反射され、第3面(23R)で裏面反射され、第2面(22R)が兼ねる第4面(24R)を経てプリズム外に射出し、右眼用の射出瞳(4R)へ導かれ、右眼に表示素子(3)の拡大像を投影する。左眼用の光路も同様。

明 細 書

画像表示装置

技 術 分 野

本発明は、画像表示装置に関し、特に、観察者の頭部又は顔面に保持することを可能にする頭部又は顔面装着式画像表示装置に関する。

背 景 技 術

従来、1つの画像表示素子の画像を両眼で観察する画像表示装置としては、特開平5-176260号、特開平9-61748号、特開平9-181998号、特開平9-181999号において知られている。

また、1つの画像表示素子の画像を両眼で観察する画像表示装置の照明方法としては、例えば特開平7-318851号において知られている。

この中、特開平5-176260号のものでは、二等辺三角柱のプリズムとミラーで光線を分割し、折り曲げているので、諸収差の補正は、瞳の前に配置するレンズで行うことになり、補正が難しくなると同時に、装置の大型化を招く。また、特開平9-61748号のものでは、LCD（液晶表示素子）の表示光をハーフミラーを利用して分割して両眼で観察する。そのために、左右それぞれの眼球へ表示光が分かれるので、観察像が弱く暗くなる。また、特開平9-181998号、特開平9-181999号のものは、プリズムが1体化であるため非常に大きく、射出成形で製作する場合、非常に時間がかかりコスト高になる。また偏心収差の補正が不十分である。

また、単一の表示素子からの表示像を両眼で観察する場合の照明方法では、特

開平 7-318851 号のような構成をとった場合、左右の眼に導かれる画像が右左逆になってしまうため、表示素子等で電氣的に表示を切り換える必要がある。

発 明 の 開 示

本発明は従来技術のこのような問題点に鑑みてなされたものであり、その目的は、1つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の中央に配置する光路振り分け手段にパワーを持たせることで、諸収差の補正を容易にした、頭部装着式画像表示装置等の画像表示装置を提供することである。また、表示画像を左右で切り換えずに使用できる単板（単一の画像表示素子）両眼視に最適な照明方法を提供することである。

上記目的を達成する本発明の画像表示装置は、観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けミラーと、前記光路振分けミラーの右側に配置された右眼用接眼プリズムと、前記光路振分けミラーの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けミラーが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束を、前記右眼用接眼プリズムと前記左眼用プリズムとに振分けて反射するミラー面を有し、前記ミラー面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記右眼用接眼プリズムが、前記光路振分けミラーで反射された右眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で右眼用光路の光束を反射する第2面と、プリズム外に右眼用光路の光束を射出する第3面とを有し、

前記左眼用接眼プリズムが、前記光路振分けミラーで反射された左眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で左眼用光路の光束を反射する第2面と、プリズム外に左眼用光路の光束を射出する第3面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第2面と、前記左眼用接眼プリズムの反射作用面である第2面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とするものである。

本発明のもう 1 つの画像表示装置は、観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第 1 面と、前記第 1 面から入射した前記右眼用光路を反射する第 2 1 面と、前記第 1 面から入射した前記左眼用光路を反射する第 2 2 面と、前記右眼用光路の光束をプリズム外に射出させる第 3 1 面と、前記左眼用光路の光束をプリズム外に射出させる第 3 2 面と、を少なくとも有し、

前記光路振分けプリズムは、前記右眼用光路中に前記画像表示素子の表示した像から右眼用リレー像を形成し、かつ、前記左眼用光路中に前記画像表示素子の表示した像から左眼用リレー像を形成するために、少なくとも前記第 2 1 面と前記第 2 2 面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第 2 1 面と前記第 2 2 面とが同一の面形状を有するように構成され、

前記右眼用接眼プリズムが、前記光路振分けプリズムの前記第 3 1 面から射出された右眼用光路の光束をプリズム内に入射させる第 1 面と、プリズム内で右眼用光路の光束を反射する第 2 面と、プリズム外に右眼用光路の光束を射出する第 3 面とを有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムの前記第 3 2 面から射出された左眼用光路の光束をプリズム内に入射させる第 1 面と、プリズム内で左眼用光路の光束を反射する第 2 面と、プリズム外に左眼用光路の光束を射出する第 3 面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第 2 面と、前記左眼用接眼プリズムの反射作用面である第 2 面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とするものである。

本発明においては、以上のような構成であるので、1 つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の

中央に配置する光路振分けミラーあるいは光路振分けプリズムを持たせることで、諸収差の補正を容易にして、頭部装着式画像表示装置等の画像表示装置を提供することができる。また、このような構成において、表示画像を左右で切り換えずに使用できる単板両眼視に最適な照明配置を得ることができる。

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

図面の簡単な説明

図 1 は本発明による実施例 1 の画像表示装置の光路図である。

図 2 は本発明による実施例 2 の画像表示装置の光路図である。

図 3 は本発明による実施例 3 の画像表示装置の光路図である。

図 4 は本発明による実施例 4 の画像表示装置の光路図である。

図 5 は本発明による実施例 5 の画像表示装置の光路図である。

図 6 は本発明による実施例 6 の画像表示装置の光路図である。

図 7 は本発明による実施例 7 の画像表示装置の光路図である。

図 8 は本発明による実施例 8 の画像表示装置の光路図である。

図 9 は本発明による実施例 9 の画像表示装置の光路図である。

図 10 は本発明による実施例 10 の画像表示装置の光路図である。

図 11 は本発明による実施例 11 の画像表示装置の光路図である。

図 12 は本発明による実施例 12 の画像表示装置の光路図である。

図 13 は本発明による実施例 13 の画像表示装置の光路図である。

図 14 は本発明による実施例 14 の画像表示装置の光路図である。

図 15 は本発明による実施例 15 の画像表示装置の光路図である。

図 16 は本発明による実施例 16 の画像表示装置を説明するための図である。

図 1 7 は本発明の実施例 1 7 の画像表示装置の両眼の光学系を示す水平断面図である。

図 1 8 は本発明の実施例 1 8 の画像表示装置の両眼の光学系を示す水平断面図である。

図 1 9 は本発明の実施例 1 9 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 0 は本発明の実施例 2 0 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 1 は本発明の実施例 2 1 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 2 は本発明の実施例 2 2 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 3 は本発明の実施例 2 3 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 4 は本発明の実施例 2 4 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 5 は本発明の実施例 2 5 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 6 は本発明の実施例 2 6 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 7 は本発明の実施例 2 7 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 8 は本発明の実施例 2 8 の画像表示装置の両眼の光学系を示す水平断面図である。

図 2 9 は本発明による実施例 2 9 ～ 3 0 の画像表示装置の光路図である。

図 3 0 はパラメータ α と β の定義を説明するための図である。

図 3 1 はパラメータ L と D の定義を説明するための図である。

図 3 2 は実施例 2 9 の右眼用の光学系の水平断面図である。

図 3 3 は実施例 3 0 の右眼用の光学系の水平断面図である。

図 3 4 は実施例 1 6 の光学系の横収差図である。

図 3 5 は実施例 2 0 の光学系の横収差図である。

図 3 6 は実施例 2 2 の光学系の横収差図である。

図 3 7 は実施例 2 9 の光学系の横収差図である。

図 3 8 は実施例 3 0 の光学系の横収差図である。

図 3 9 は本発明の画像表示装置をシースルー観察可能に構成した場合の構成を説明するための図である。

図 4 0 は有機 E L 画像表示素子の構造を例示する斜視図である。

図 4 1 は本発明の画像表示装置を観察者頭部に装着した場合の様子を示す図である。

発明を実施するための最良の形態

以下に、本発明の画像表示装置を実施例に基づいて説明する。図 1 ～図 1 5 にそれぞれ本発明による実施例 1 ～1 6 の画像表示装置の光路図を示す。

図 1 の実施例 1 において、観察者の右眼を E R で、左眼を E L で、画像表示装置の画像表示素子を符号 3 で、右眼用の射出瞳を 4 R で、左眼用の射出瞳を 4 L で示し、右眼用の光学系で右眼前に配置する偏心プリズム体を 2 R、左眼用の光学系で左眼前に配置する偏心プリズム体を 2 L で示す。さらに、両眼の中央に配置する光路振分けミラーを 1 で示す。偏心プリズム体 2 R、2 L は屈折率が 1 より大きい透明媒体からなっている。また、下記の説明において、反射面と説明している面は、全反射面以外は偏心プリズム体の対象の面にミラーコートをしてミラー面としたものである。

この実施例 1 は、図 1 に水平断面（Y-Z 断面）を示すような構成になっており、中央の光路振分けミラー 1 は、両眼の対称面（右眼用射出瞳 4 R と左眼用射出瞳 4 L の中心間を結んだ線分の中心を通りその線分に垂直な平面）に対して面対称な形状の右光路用反射面 1 R と左光路用反射面 1 L とからなる。

右眼用の光学系を構成する偏心プリズム体 2 R と左眼用の光学系を構成する偏

心プリズム体 2 L とは同一形状のもので、両眼の対称面に対して面对称に配置され、それぞれ光線が通る順番で、第 1 面 2 1 R (2 1 L) 、第 2 面 2 2 R (2 2 L) 、第 3 面 2 3 R (2 3 L) 、第 4 面 2 4 R (2 4 L) から構成されており、第 2 面 2 2 R (2 2 L) と第 4 面 2 4 R (2 4 L) は同一面からなり、その同一面は全反射面と透過面を兼ねている。

画像表示素子 3 は、光路振分けミラー 1 に面してその観察者側に配置される。偏心プリズム体 2 R、2 L の第 4 面 2 4 R、2 4 L それぞれに面して略同一面上に射出瞳 4 R、4 L が位置している。そして、各偏心プリズム体 2 R、2 L、光路振分けミラー 1 の各面 2 1 R ~ 2 4 R、2 1 L ~ 2 4 L、1 R、1 L は、後記の式 (a) で表される自由曲面から構成されている。また、各自由曲面は、平面を含む球面、非球面、アナモフィック面、アナモフィック非球面に置き換えることも可能である。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けミラー 1 の反射面 1 R に入射して反射され、偏心プリズム体 2 R に入射する。入射光は第 1 面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。なお、画像表示素子 3 から射出瞳 4 R へ到る光路中には中間像は結像されない。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、3 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも 1 面が正パワーを有する反射面及び透過面を経て画像表示素子 3 の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、左右の光路振分けのために光路振分けミラ

ー 1 の 1 面にすることで、多数面あるプリズムより製造が簡単で表示装置を軽量化できる利点がある。また、画像表示素子 3 が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平 9 - 6 1 7 4 8 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けミラー 1 の反射面 1 R、1 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の光路振分けミラー 1 に対して面对称な位置に配置すればよい。

実施例 2 は、図 2 に水平断面（Y-Z 断面）を示すように、実施例 1 の配置において、画像表示素子 3 から光路振分けミラー 1 の右光路用反射面 1 R と左光路用反射面 1 L に至る光路中に共通の負レンズ 5 を挿入したもので、その他の配置、光路は実施例 1 と同じであり、同様に中間像は結像されない。この負レンズ 5 の代わりにあるいはそれに加えて回折光学素子やレンチキュラーレンズを用いてもよい。画像表示素子 3 から光路振分けミラー 1 の間に負レンズ 5 等を挿入することにより、収差補正がさらに良好になる。また、回折光学素子やレンチキュラーレンズを用いることにより、左右の光路分割がよりしやすくなる。

実施例 3 は、図 3 に水平断面（Y-Z 断面）を示すように、実施例 1 ~ 2 の両眼の中央に配置する光路振分けミラー 1 の代わりに、5 面の偏心プリズム体からなる光路振分けプリズム 1 0 を用いたものである。左右の眼用の偏心プリズム体 2 L、2 R は実施例 1 ~ 2 と同様である。

中央の光路振分けプリズム 1 0 は、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者側に位置する右光路用反射面の第 2 面 1 2 R と左光路用反射面の第 2 面 1 2 L、さらにそれら第 2 面 1 2 R、1 2 L の観察者側に位置する左光路用透過面 1 3 L、右光路用透過面 1 3 R の 5 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 2 面 1 2 R と 1 2 L は両眼の対称面に対して面对称

な形状、第3面13Lと13Rは両眼の対称面に対して面对称な形状である。画像表示素子3は、光路振分けプリズム10の第1面11に面して、光路振分けプリズム10の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けプリズム10の第1面11に入射し、その右光路用反射面の第2面12Rに入射して反射され、右光路用透過面13Rを透過して、偏心プリズム体2Rに入射する。入射光は第1面21Rを透過してプリズム内に入射し、第2面22Rに臨界角以上の入射角で入射して全反射され、第3面23Rに入射して裏面反射され、第4面24Rに臨界角以下の入射角で入射して屈折されて偏心プリズム体2Rから射出し、右眼用の射出瞳4Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子3からの表示光は、3回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも1面が正パワーを有する反射面及び透過面を経て画像表示素子3の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を1回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム10の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム10の反射面12R、12Lは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。さらに、画像表示素子3が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平9-

6 1 7 4 8 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム 1 0 の反射面 1 2 R、1 2 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 1 0、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 1 0 に対して面对称な位置に配置すればよい。

実施例 4 は、図 4 に水平断面（Y-Z 断面）を示すように、実施例 1～2 の両眼の中央に配置する光路振分けミラー 1 の代わりに、5 面の偏心プリズム体からなる光路振分けプリズム 1 0 を用いたものである。左右の眼用の偏心プリズム体 2 L、2 R は実施例 1～2 と同様である。実施例 3 との大きな違いは、画像表示素子 3 が、光路振分けプリズム 1 0 の観察者側に配置されている点である。

中央の光路振分けプリズム 1 0 は、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者と反対側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者と反対側に位置する右光路用透過面の第 3 面 1 3 R、左光路用透過面の第 3 面 1 3 L、さらにそれら第 3 面 1 3 R、1 3 L の観察者と反対側に位置する左光路用反射面の第 2 面 1 2 L と右光路用反射面の第 2 面 1 2 R の 5 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 3 面 1 3 R と 1 3 L、第 2 面 1 2 L と 1 2 R は両眼の対称面に対して面对称な形状である。画像表示素子 3 は、光路振分けプリズム 1 0 の第 1 面 1 1 に面して、光路振分けプリズム 1 0 の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 1 0 の第 1 面 1 1 に入射し、その右光路用反射面の第 2 面 1 2 R に入射して反射され、右光路用透過面 1 3 R を透過し

て、偏心プリズム体 2 R に入射する。入射光は第 1 面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、3 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも 1 面が正パワーを有する反射面及び透過面を経て画像表示素子 3 の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を 1 回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム 1 0 の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム 1 0 の反射面 1 2 R、1 2 L は全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。また、画像表示素子 3 が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平 9 - 6 1 7 4 8 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム 1 0 の反射面 1 2 R、1 2 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 1 0、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏

心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 1 0 に対して面对称な位置に配置すればよい。

実施例 5 は、図 5 に水平断面（Y-Z 断面）を示すように、実施例 3～4 の 5 面の偏心プリズム体からなる光路振分けプリズム 1 0 の代わりに 3 面の偏心プリズム体からなる光路振分けプリズム 1 0 を用いたものである。左右の眼用の偏心プリズム体 2 L、2 R は実施例 1～4 と同様である。

中央の光路振分けプリズム 1 0 は、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者側に位置する全反射面として作用する右光路用反射面の第 2 面 1 2 R と左光路用反射面の第 2 面 1 2 L、右光路用反射面の第 2 面 1 2 R と同一面の左光路用透過面 1 3 L、左光路用反射面の第 2 面 1 2 L と同一面の右光路用透過面 1 3 R の 3 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 2 面 1 2 R（1 3 L）と 1 2 L（1 3 R）は両眼の対称面に対して面对称な形状である。画像表示素子 3 は、光路振分けプリズム 1 0 の第 1 面 1 1 に面して、光路振分けプリズム 1 0 の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 1 0 の第 1 面 1 1 に入射し、その右光路用反射面の第 2 面 1 2 R に入射して全反射され、右光路用透過面 1 3 R（1 2 L）を透過して、偏心プリズム体 2 R に入射する。入射光は第 1 面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、3 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも 1 面が正パワーを有する反射面及び透過面を経て画像表示素子 3 の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を 1 回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム 10 の射出面と反射面が兼用面であるため、光路振分けプリズム 10 の有効面が 3 面のみであるため、製造が非常に簡単である。さらに、画像表示素子 3 が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平 9 - 6 1 7 4 8 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム 10 の反射面 12 R、12 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 10、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 10 に対して面对称な位置に配置すればよい。

実施例 6 は、図 6 に水平断面（Y-Z 断面）を示すように、実施例 3～4 の 5 面の偏心プリズム体からなる光路振分けプリズム 10 の代わりに 6 面の偏心プリズム体からなる光路振分けプリズム 10 を用いたものである。左右の眼用の偏心プリズム体 2 L、2 R は実施例 1～5 と同様である。

中央の光路振分けプリズム 10 は、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 11 が透過面、その第 1 面 11 に面していて観察者に面する反射面の第 2 面 12、第 1 面 11 の観察者側両側に配

置された右光路用反射面の第3面13Rと左光路用反射面の第3面13L、第3面13R、13Lと第2面12の間の両側に配置された左光路用透過面の第4面14L、右光路用透過面の第4面14Rの6面からなる。第1面11、第2面12は両眼の対称面に対して面対称な形状、第3面13Rと13L、第4面14Lと14Rは両眼の対称面に対して面対称な形状である。画像表示素子3は、光路振分けプリズム10の第1面11に面して、光路振分けプリズム10の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けプリズム10の左右共通の第1面11に入射し、左右共通の第2面12で反射され、右光路用反射面の第3面13Rに入射して反射され、右光路用透過面14Rを透過して、偏心プリズム体2Rに入射する。入射光は第1面21Rを透過してプリズム内に入射し、第2面22Rに臨界角以上の入射角で入射して全反射され、第3面23Rに入射して裏面反射され、第4面24Rに臨界角以下の入射角で入射して屈折されて偏心プリズム体2Rから射出し、右眼用の射出瞳4Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子3からの表示光は、4回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも1面が正パワーを有する反射面及び透過面を経て画像表示素子3の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を1回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム10が2回反射の構成であるので、非常に良好に偏心収

差の補正が可能である。さらに、画像表示素子 3 が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平 9 - 6 1 7 4 8 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム 1 0 の反射面 1 2、1 3 R、1 3 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 1 0、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 1 0 に対して面对称な位置に配置すればよい。

実施例 7 は、図 7 に水平断面（Y-Z 断面）を示すように、右眼用の光学系を構成する偏心プリズム体 2 R と左眼用の光学系を構成する偏心プリズム体 2 L とは同一形状のもので、両眼の対称面に対して面对称に配置され、それぞれ光線が通る順番で、第 1 面 2 1 R（2 1 L）、第 2 面 2 2 R（2 2 L）、第 3 面 2 3 R（2 3 L）、第 4 面 2 4 R（2 4 L）、第 5 面 2 5 R（2 5 L）から構成されており、第 3 面 2 3 R（2 3 L）と第 5 面 2 5 R（2 5 L）は同一面からなり、その同一面は全反射面と透過面を兼ねている。

中央の光路振分けプリズム 1 0 は、実施例 4（図 4）と同様に、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者側に位置する右光路用透過面の第 3 面 1 3 R、左光路用透過面の第 3 面 1 3 L、さらにそれら第 3 面 1 3 R、1 3 L の観察者側に位置する左光路用反射面の第 2 面 1 2 L と右光路用反射面の第 2 面 1 2 R の 5 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 3 面 1 3 R と 1 3 L、第 2 面 1 2 L と 1 2 R は両眼の対称面に対して面对称な形状である。画像表示素子 3 は、光路振分けプリズム 1 0 の第 1 面 1 1 に面して、光路振分けプリズム 1 0 の観察者と反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けプリズム10の第1面11に入射し、その右光路用反射面の第2面12Rに入射して反射され、右光路用透過面13Rを透過して、偏心プリズム体2Rに入射する。入射光は第1面21Rを透過してプリズム内に入射し、第2面22Rで反射され、その反射光は第3面23Rに臨界角以上の入射角で入射して全反射され、第4面24Rに入射して裏面反射され、第5面25Rに臨界角以下の入射角で入射して屈折されて偏心プリズム体2Rから射出し、右眼用の射出瞳4Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子3からの表示光は、4回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも1面が正パワーを有する反射面及び透過面を経て画像表示素子3の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を1回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム10の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム10の反射面12R、12Lは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。さらに、画像表示素子3が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平9-61748号のようにハーフミラーを利用せず、共通の1枚の画像表示素子3からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム10の反射面12R、12Lに自由曲面を用いることにより、偏心収差を非常に

良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が1より大きい透明媒体で満たされた偏心プリズム体10、2R、2L中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体2R、2Lは面对称な位置に配置されるが、その形状は同一なものである、同じ形状の2つの偏心プリズム体2R、2Lを用意し、中央の偏心プリズム体10に対して面对称な位置に配置すればよい。

実施例8は、図8に水平断面(Y-Z断面)を示すように、実施例7の5面の偏心プリズム体からなる光路振分けプリズム10の代わりに、実施例5(図5)と同様の3面の偏心プリズム体からなる光路振分けプリズム10を用いたものである。左右の眼用の偏心プリズム体2L、2Rは実施例7と同様である。

中央の光路振分けプリズム10は、実施例5(図5)と同様に、両眼の対称面に対して面对称な形状であり、画像表示素子3の観察者と反対側に位置する第1面11が透過面、その第1面11の両側で観察者側に位置する全反射面として作用する右光路用反射面の第2面12Rと左光路用反射面の第2面12L、右光路用反射面の第2面12Rと同一面の左光路用透過面13L、左光路用反射面の第2面12Lと同一面の右光路用透過面13Rの3面からなる。第1面11は両眼の対称面に対して面对称な形状、第2面12R(13L)と12L(13R)は両眼の対称面に対して面对称な形状である。画像表示素子3は、光路振分けプリズム10の第1面11に面して、光路振分けプリズム10の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けプリズム10の第1面11に入射し、その右光路用反射面の第2面12Rに入射して全反射され、右光路用透過面13R(12L)を透過して、偏心プリズム体2Rに入射する。入射光は第1面21Rを透過してプリズム内に入射し、第2面22Rで反射され、その反射光は第3面23Rに臨界角以上の入射角で入射して全反射され、第4面24Rに入射して裏面反射

され、第5面25Rに臨界角以下の入射角で入射して屈折されて偏心プリズム体2Rから射出し、右眼用の射出瞳4Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子3からの表示光は、4回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも1面が正パワーを有する反射面及び透過面を経て画像表示素子3の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を1回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム10の射出面と反射面が兼用面であるため、光路振分けプリズム10の有効面が3面のみであるため、製造が非常に簡単である。また、画像表示素子3が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平9-61748号のようにハーフミラーを利用せず、共通の1枚の画像表示素子3からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム10の反射面12R、12Lに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が1より大きい透明媒体で満たされた偏心プリズム体10、2R、2L中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体2R、2Lは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の2つの偏心プリズム体2R、2Lを用意し、中央の偏心プリズム体10に対して面対称な位置に配置すればよい。

実施例9は、図9に水平断面(Y-Z断面)を示すように、実施例7の5面の偏心プリズム体からなる光路振分けプリズム10の代わりに、実施例6(図6)

と同様の 6 面の偏心プリズム体からなる光路振分けプリズム 10 を用いたものである。左右の眼用の偏心プリズム体 2 L、2 R は実施例 7 と同様である。

中央の光路振分けプリズム 10 は、実施例 6（図 6）と同様に、両眼の対称面に対して面対称な形状であり、画像表示素子 3 の観察者と反対側に位置する第 1 面 11 が透過面、その第 1 面 11 に面していて観察者と反対側の反射面の第 2 面 12、第 1 面 11 の観察者と反対側両側に配置された右光路用反射面の第 3 面 13 R と左光路用反射面の第 3 面 13 L、第 3 面 13 R、13 L と第 2 面 12 の間の両側に配置された左光路用透過面の第 4 面 14 L、右光路用透過面の第 4 面 14 R の 6 面からなる。第 1 面 11、第 2 面 12 は両眼の対称面に対して面対称な形状、第 3 面 13 R と 13 L、第 4 面 14 L と 14 R は両眼の対称面に対して面対称な形状である。画像表示素子 3 は、光路振分けプリズム 10 の第 1 面 11 に面して、光路振分けプリズム 10 の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 10 の左右共通の第 1 面 11 に入射し、左右共通の第 2 面 12 で反射され、右光路用反射面の第 3 面 13 R に入射して反射され、右光路用透過面 14 R を透過して、偏心プリズム体 2 R に入射する。入射光は第 1 面 21 R を透過してプリズム内に入射し、第 2 面 22 R で反射され、その反射光は第 3 面 23 R に臨界角以上の入射角で入射して全反射され、第 4 面 24 R に入射して裏面反射され、第 5 面 25 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、5 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配

置された少なくとも1面が正パワーを有する反射面及び透過面を経て画像表示素子3の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を1回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム10が2回反射の構成であるので、非常に良好に偏心収差の補正が可能である。また、画像表示素子3が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平9-61748号のようにハーフミラーを利用せず、共通の1枚の画像表示素子3からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム10の反射面12、13R、13Lに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が1より大きい透明媒体で満たされた偏心プリズム体10、2R、2L中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体2R、2Lは面对称な位置に配置されるが、その形状は同一なものである、同じ形状の2つの偏心プリズム体2R、2Lを用意し、中央の偏心プリズム体10に対して面对称な位置に配置すればよい。

実施例10は、図10に水平断面(Y-Z断面)を示すように、実施例8(図8)の4面の偏心プリズム体からなる右眼用の偏心プリズム体2Rと左眼用の偏心プリズム体2Lの代わりに、3面の同一形状の偏心プリズム体からなる右眼用の偏心プリズム体2Rと左眼用の偏心プリズム体2Lとを、両眼の対称面に対して面对称に配置したもので、光路振分けプリズム10は同様である。偏心プリズム体2Rの第1面21Rを透過してプリズム内に入射した光は、第2面22Rで反射され、その反射光は第3面23Rで屈折されて偏心プリズム体2Rから射出し、右眼用の射出瞳4Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を

挟んで、右眼用の光路と面对称な関係になる。その他は、実施例 8 と同じである。

実施例 1 1 は、図 1 1 に水平断面（Y-Z 断面）を示すように、実施例 7（図 7）の 4 面の偏心プリズム体からなる右眼用の偏心プリズム体 2 R と左眼用の偏心プリズム体 2 L の代わりに、3 面の同一形状の偏心プリズム体からなる右眼用の偏心プリズム体 2 R と左眼用の偏心プリズム体 2 L とを、両眼の対称面に対して面对称に配置したもので、光路振分けプリズム 1 0 は同様である。偏心プリズム体 2 R の第 1 面 2 1 R を透過してプリズム内に入射した光は、第 2 面 2 2 R で反射され、その反射光は第 3 面 2 3 R で屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。その他は、実施例 7 と同じである。

実施例 1 2 は、図 1 2 に水平断面（Y-Z 断面）を示すように、7 面の偏心プリズム体からなる光路振分けプリズム 1 0 を用いたものである。また、右眼用の光学系を構成する偏心プリズム体 2 R と左眼用の光学系を構成する偏心プリズム体 2 L とは同一形状のもので、両眼の対称面に対して面对称に配置され、それぞれ光線が通る順番で、第 1 面 2 1 R（2 1 L）、第 2 面 2 2 R（2 2 L）、第 3 面 2 3 R（2 3 L）、第 4 面 2 4 R（2 4 L）から構成されているものである。

中央の光路振分けプリズム 1 0 は、両眼の対称面に対して面对称な形状であり、観察者と反対側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者と反対側に位置する右光路用反射面の第 3 面 1 3 R、左光路用反射面の第 3 面 1 3 L、さらにそれら第 3 面 1 3 R、1 3 L の観察者側に位置する左光路用透過面の第 4 面 1 4 L と右光路用透過面の第 4 面 1 4 R、さらにそれら第 4 面 1 4 R、1 4 L の観察者側に位置する左光路用反射面の第 2 面 1 2 L と右光路用反射面の第 2 面 1 2 R の 7 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 3 面 1 3 R と 1 3 L、第 4 面 1 4 L と 1 4 R、第 2 面 1 2 L と 1 2 R は両

眼の対称面に対して面対称な形状である。画像表示素子 3 は、光路振分けプリズム 10 の第 1 面 11 に面して、光路振分けプリズム 10 の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 10 の第 1 面 11 に入射し、その右光路用反射面の第 2 面 12 R に入射して反射され、次の右光路用反射面の第 3 面 13 R に入射して反射され、右光路用透過面 14 R を透過して、偏心プリズム体 2 R に入射する。入射光は第 1 面 21 R を透過してプリズム内に入射し、第 2 面 22 R に入射して裏面反射され、第 3 面 23 R に入射して裏面反射され、第 4 面 24 R で屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、4 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも 1 面が正パワーを有する反射面及び透過面を経て画像表示素子 3 の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を 1 回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム 10 の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム 10 の反射面 12 R、12 L、13 R、13 L は全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。また、画像表示素子 3 が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さら

に、特開平 9-61748 号のようにハーフミラーを利用せず、共通の 1 枚の画像表示素子 3 からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム 10 の反射面 12 R、12 L、13 R、13 L に自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 10、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 10 に対して面对称な位置に配置すればよい。

この実施例においては、光路振分けプリズム 10、偏心プリズム体 2 R、2 L 何れにおいても、全反射面を用いていない。全反射面を用いる場合、全反射条件を満足させるためには光線の入射角を非常に大きくする必要がある。しかし、入射角の大きい面にパワーを持たせると偏心収差が大きく発生し、弱いパワーしか持たせることができないが、このような全反射面を用いていない本実施例においては、通常の反射を利用することで各面にパワーを均等に配分し、非常に良好に偏心収差を補正することが可能となる。また、各偏心プリズム 10、2 R、2 L 中で光路を交差させているため、接眼プリズムの光路長を大きく取ることができる。そのため、中間結像位置が接眼プリズムの中に形成できる。したがって、中間像から表示素子までの物像間距離が長く取れ、光路振り分けプリズム 10 のパワーを弱く設定することができる。そのため、良好な結像性能を確保することができる。

実施例 13～15 は、画像表示素子 3 の照明光学系に関する実施例であり、図 13 の実施例 13 は、図 5 の実施例 5 の左右の光学系配置において、画像表示素子 3 として透過型の LCD（液晶表示素子）を用い、その背後（光路振分けプリズム 10 と反対側）に左右の光路用の照明光源 6 R、6 L を配置し、光源 6 R、6 L と画像表示素子 3 の間に集光用フレネルレンズ 7 を配置した実施例である。

この実施例においては、左光路用の照明光源 6 L からの照明光はフレネルレン

ズ 7 で集光されて画像表示素子 3 に入射し、その表示光は図 5 の左眼用光路を経て観察者の左眼 E L に達し、画像表示素子 3 の拡大像を投影する。また、右光路用の照明光源 6 R からの照明光はフレネルレンズ 7 で集光されて画像表示素子 3 に入射し、その表示光は図 5 の右眼用光路を経て観察者の左眼 E R に達し、画像表示素子 3 の拡大像を投影する。

この場合、左右共通の 1 枚の画像表示素子 (L D C) 3 の左右眼用の照明光学系 7 と光路振分けプリズム 1 0 を共有化することで、光学部材の削減が可能であり、また、小型軽量で明るい表示装置が可能となる。なお、この例の場合は、照明光学系にもハーフミラーを用いていないため、非常に明るい画像表示が可能になる。

図 1 4 の実施例 1 4 は、図 6 の実施例 6 の左右の光学系配置において、画像表示素子 3 として反射型の L C D (液晶表示素子) 3' を用い、光路振分けプリズム 1 0 を横切って照明可能に左右の光路用の照明光源 6 R、6 L を配置し、光路振分けプリズム 1 0 の第 2 面 1 2 をハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、その第 2 面 1 2 と第 1 面 1 1 とを経て光源 6 R、6 L からの照明光で反射型 L C D 3' を照明するようにした実施例である。

この実施例においては、左光路用の照明光源 6 L からの照明光は、光路振分けプリズム 1 0 の第 2 面 1 2 のハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム 1 0 を横切ってその第 1 面 1 1 を透過して反射型 L C D 3' の表示面に入射し、反射した表示光は図 6 の左眼用光路を経て観察者の左眼 E L に達し、画像表示素子 3 の拡大像を投影する。また、右光路用の照明光源 6 R からの照明光も、同様に光路振分けプリズム 1 0 の第 2 面 1 2 のハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム 1 0 を横切ってその第 1 面 1 1 を透過して反射型 L C D 3' の表示面に入射し、反射した表示光は図 6 の右眼用光路を経て観察者の右眼 E R に達し、画像表示素子 3 の拡大像を投影する。

この場合、左右共通の 1 枚の反射型 L C D 3' の左右眼用の照明光学系と光路振分けプリズム 1 0 を共有化することで、光学部材の削減が可能であり、また、

小型軽量で明るい表示装置が可能となる。なお、この例の場合は、光路振分けプリズム（兼用照明プリズム）10は有効面が6面あるため、反射型LCD3'を均一に照明でき、さらに偏心収差を良好に補正することが可能である。

図15の実施例15は、図4の実施例4の左右の光学系配置において、画像表示素子3として反射型LCD3'を用い、光路振分けプリズム10を横切って照明可能に左右の光路用の照明光源6R、6Lを配置し、光路振分けプリズム10の左右の光路用の第2面12L、12Rをハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、その第2面12L、12Rと第1面11とを経て光源6R、6Lからの照明光で反射型LCD3'を照明するようにした実施例である。

この実施例においては、左光路用の照明光源6Lからの照明光は、光路振分けプリズム10の右眼用光路の第2面12Rのハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム10を横切ってその第1面11を透過して反射型LCD3'の表示面に入射し、反射した表示光は図4の左眼用光路を経て観察者の左眼ELに達し、画像表示素子3の拡大像を投影する。また、右光路用の照明光源6Rからの照明光も、同様に光路振分けプリズム10の左眼用光路の第2面12Lのハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム10を横切ってその第1面11を透過して反射型LCD3'の表示面に入射し、反射した表示光は図4の右眼用光路を経て観察者の右眼ERに達し、画像表示素子3の拡大像を投影する。

この場合、左右共通の1枚の反射型LCD3'の左右眼用の照明光学系と光路振分けプリズム10を共有化することで、光学部材の削減が可能であり、また、小型軽量で明るい表示装置が可能となる。なお、この例の場合は、光路振分けプリズム10と照明光学系を共有にしながら、照明光学系の入射面及び射出面を共に共有化することで、光路振分けプリズム10の小型軽量化が可能である。

なお、図13～図15のような左右の光路用の照明光源6R、6L、集光用フレネルレンズ7の配置、反射面をハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、透過型あるいは反射型の画像表示素子3を照明できること

は、図4～図6の以外の前記実施例においても同様である。

ところで、前記したように、上記のような本発明の画像表示装置用の光学系において、光路振分けミラー1の反射面1R、1L、光路振分けプリズム10の各面11、12、12R、12L、13R、13L、14R、14L、右眼用接眼光学系の偏心プリズム体2Rの面21R～25R、右眼用接眼光学系の偏心プリズム体2Lの面21L～25Lに用いる面としては、偏心収差を補正するような回転非対称な曲面形状にて構成することが望ましい。

ここで、本発明における右眼用接眼プリズム2R、左眼用接眼プリズム2L、光路振分けプリズム10、光路振分けミラー1は、基本的に、偏心光学系であり、偏心収差を補正する回転非対称な曲面形状の光学面を少なくとも1面含むものとして構成するのが望ましい。

偏心光学系を頭部装着式の画像表示装置の観察光学系として用いる場合、デッドスペースをなくし、装置全体をより小型化するためには、画像表示素子の位置、並びに、偏心光学系を構成する光学面の配置位置を、装置内部でなるべくコンパクトに収まる位置に配置する必要がある。そうすると、光学系は必然的に3次元的に偏心した配置とならざるを得ず、回転非対称な収差が発生し、これを回転対称な光学系でのみ補正することは不可能であり、この3次元的な偏心により発生する回転非対称な収差を補正する最良な面形状は回転非対称面である。したがって、本発明の画像表示装置においては、光路振分けミラー1の反射面1R、1L、光路振分けプリズム10の各面11、12、12R、12L、13R、13L、14R、14L、右眼用接眼光学系の偏心プリズム体2Rの面21R～25R、右眼用接眼光学系の偏心プリズム体2Lの面21L～25Lの中、少なくとも1面、好ましくは反射面の形状を、偏心収差を補正するような回転非対称な曲面形状にて構成することが望ましい。

ここで、回転非対称な曲面形状の面として、本発明で使用する自由曲面とは以下の式で定義されるものである。この定義式のZ軸が自由曲面の軸となる。

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$$Z = c r^2 / [1 + \sqrt{\{1 - (1 + k) c^2 r^2\}}] + \sum C_j X^m Y^n$$

$$j=2$$

... (a)

ここで、(a) 式の第 1 項は球面項、第 2 項は自由曲面項である。

球面項中、

c : 頂点の曲率

k : コーニック定数 (円錐定数)

$$r = \sqrt{(X^2 + Y^2)}$$

である。

自由曲面項は、

66

$$\sum_{j=2} C_j X^m Y^n$$

j=2

$$\begin{aligned} &= C_2 X + C_3 Y \\ &+ C_4 X^2 + C_5 XY + C_6 Y^2 \\ &+ C_7 X^3 + C_8 X^2 Y + C_9 XY^2 + C_{10} Y^3 \\ &+ C_{11} X^4 + C_{12} X^3 Y + C_{13} X^2 Y^2 + C_{14} XY^3 + C_{15} Y^4 \\ &+ C_{16} X^5 + C_{17} X^4 Y + C_{18} X^3 Y^2 + C_{19} X^2 Y^3 + C_{20} XY^4 \\ &\quad + C_{21} Y^5 \\ &+ C_{22} X^6 + C_{23} X^5 Y + C_{24} X^4 Y^2 + C_{25} X^3 Y^3 + C_{26} X^2 Y^4 \\ &\quad + C_{27} XY^5 + C_{28} Y^6 \\ &+ C_{29} X^7 + C_{30} X^6 Y + C_{31} X^5 Y^2 + C_{32} X^4 Y^3 + C_{33} X^3 Y^4 \\ &\quad + C_{34} X^2 Y^5 + C_{35} XY^6 + C_{36} Y^7 \\ &\quad \dots \end{aligned}$$

ただし、 C_j (j は 2 以上の整数) は係数である。

上記自由曲面は、一般的には、 $X-Z$ 面、 $Y-Z$ 面共に対称面を持つことはないが、 X の奇数次項を全て 0 にすることによって、 $Y-Z$ 面と平行な対称面が 1 つだけ存在する自由曲面となる。また、 Y の奇数次項を全て 0 にすることによって、 $X-Z$ 面と平行な対称面が 1 つだけ存在する自由曲面となる。

また、上記の回転非対称な曲面形状の面である自由曲面の他の定義式として、Zernike多項式により定義できる。この面の形状は以下の式（b）により定義する。その定義式（b）のZ軸がZernike多項式の軸となる。回転非対称面の定義は、X-Y面に対するZの軸の高さの極座標で定義され、AはX-Y面内のZ軸からの距離、RはZ軸回りの方位角で、Z軸から測った回転角で表せられる。

$$\begin{aligned}
 x &= R \times \cos(A) \\
 y &= R \times \sin(A) \\
 Z &= D_2 \\
 &+ D_3 R \cos(A) + D_4 R \sin(A) \\
 &+ D_5 R^2 \cos(2A) + D_6 (R^2 - 1) + D_7 R^2 \sin(2A) \\
 &+ D_8 R^3 \cos(3A) + D_9 (3R^3 - 2R) \cos(A) \\
 &\quad + D_{10} (3R^3 - 2R) \sin(A) + D_{11} R^3 \sin(3A) \\
 &+ D_{12} R^4 \cos(4A) + D_{13} (4R^4 - 3R^2) \cos(2A) \\
 &\quad + D_{14} (6R^4 - 6R^2 + 1) + D_{15} (4R^4 - 3R^2) \sin(2A) \\
 &\quad + D_{16} R^4 \sin(4A) \\
 &+ D_{17} R^5 \cos(5A) + D_{18} (5R^5 - 4R^3) \cos(3A) \\
 &\quad + D_{19} (10R^5 - 12R^3 + 3R) \cos(A) \\
 &\quad + D_{20} (10R^5 - 12R^3 + 3R) \sin(A) \\
 &\quad + D_{21} (5R^5 - 4R^3) \sin(3A) + D_{22} R^5 \sin(5A) \\
 &+ D_{23} R^6 \cos(6A) + D_{24} (6R^6 - 5R^4) \cos(4A) \\
 &\quad + D_{25} (15R^6 - 20R^4 + 6R^2) \cos(2A) \\
 &\quad + D_{26} (20R^6 - 30R^4 + 12R^2 - 1) \\
 &\quad + D_{27} (15R^6 - 20R^4 + 6R^2) \sin(2A) \\
 &\quad + D_{28} (6R^6 - 5R^4) \sin(4A) + D_{29} R^6 \sin(6A) \cdot \cdot \cdot \cdot \\
 &\quad \cdot \cdot \cdot \cdot (b)
 \end{aligned}$$

ただし、 D_m （ m は2以上の整数）は係数である。なお、X軸方向に対称な光学系として設計するには、 D_4 、 D_5 、 D_6 、 D_{10} 、 D_{11} 、 D_{12} 、 D_{13} 、 D_{14} 、 D

$z_0, D_{21}, D_{22} \dots$ を利用する。

上記定義式は、回転非対称な曲面形状の面の例示のために示したものであり、他のいかなる定義式に対しても同じ効果が得られることは言うまでもない。

そして、光路振分けプリズム光路振分けミラー 1、光路振分けプリズム 1 0、右眼用接眼プリズム体 2 R、右眼用接眼プリズム体 2 L の有する自由曲面が、画像表示素子の表示画像中心と瞳中心とを結んだ光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Y-Z 平面）を唯一の対称面として構成されていることが望ましい。

なお、自由曲面の他の定義式の例として、次の定義式（c）があげられる。

$$Z = \sum \sum C_{nm} X^m Y^n$$

例として、 $k=7$ （7 次項）を考えると、展開したとき、以下の式で表せる。

$$\begin{aligned} Z = & C_2 \\ & + C_3 Y + C_4 |X| \\ & + C_5 Y^2 + C_6 Y |X| + C_7 X^2 \\ & + C_8 Y^3 + C_9 Y^2 |X| + C_{10} Y X^2 + C_{11} |X^3| \\ & + C_{12} Y^4 + C_{13} Y^3 |X| + C_{14} Y^2 X^2 + C_{15} Y |X^3| + C_{16} X^4 \\ & + C_{17} Y^5 + C_{18} Y^4 |X| + C_{19} Y^3 X^2 + C_{20} Y^2 |X^3| \\ & \quad + C_{21} Y X^4 + C_{22} |X^5| \\ & + C_{23} Y^6 + C_{24} Y^5 |X| + C_{25} Y^4 X^2 + C_{26} Y^3 |X^3| \\ & \quad + C_{27} Y^2 X^4 + C_{28} Y |X^5| + C_{29} X^6 \\ & + C_{30} Y^7 + C_{31} Y^6 |X| + C_{32} Y^5 X^2 + C_{33} Y^4 |X^3| \\ & \quad + C_{34} Y^3 X^4 + C_{35} Y^2 |X^5| + C_{36} Y X^6 + C_{37} |X^7| \\ & \quad \dots (c) \end{aligned}$$

なお、左右眼用の接眼プリズム 2 L、2 R の最も射出瞳側の屈折面（実施例 1～6 の面 2 4 L、2 4 R、実施例 7～9 の面 2 5 L、2 5 R、実施例 10～11 の面 2 3 L、2 3 R）を回転対称非球面にて構成してもよい。この場合は、製作性が向上すると共に、この回転対称非球面を基準面にして他の面の位置出しが容易になる。

また、以上の実施例における左右眼用の光学系を構成する偏心プリズム体 2 L、2 R としては、公知の他のタイプの偏心プリズム体を用いてもよい。

さて、次に、本発明による具体的な数値例として、実施例 16～30 の画像表示装置について説明する。

図 16 は、実施例 16 の画像表示装置を説明するための図であり、図 16 (a) は両眼の光学系を示す水平断面 (Y-Z 断面) であり、図 16 (b) は右眼用の光学系のみを示す水平断面である。以下、実施例 17～28 については、それぞれ図 17～図 27 に、図 16 (a) と同様の両眼の光学系を示す水平断面図を示す。

何れの実施例の光学系も、前記の実施例 1～15 と同様に、両眼の対称面に対して面対称な形状であるので、図 16 (b) のような右眼用の光学系の逆光線追跡での構成パラメータのみを後記してある。後記する実施例 16～28 の逆光線追跡での構成パラメータは、図 16 (b) に示すように、軸上主光線 (光軸) O を、光学系の射出瞳 4 R の中心を垂直に通り、画像表示素子 3 中心に至る光線で定義する。そして、逆光線追跡において、瞳 4 R の中心を偏心光学系の偏心光学面の原点として、軸上主光線 O に沿う方向を Z 軸方向とし、瞳 4 R から光学系の最終面 (逆光線追跡では最初の面: 入射面。図 16 (b) では第 4 面 24 R) に向かう方向を Z 軸正方向とし、この Z 軸と画像表示素子 3 中心を含む平面を Y-Z 平面とし、原点を通り Y-Z 平面に直交し、紙面の手前から裏面側に向かう方向を X 軸正方向とし、X 軸、Z 軸と右手直交座標系を構成する軸を Y 軸とする。図 16 (b) には、この座標系を図示してある。実施例 17～28 を示す図 17～図 27 については、この座標系の図示は省く。

実施例 16～30 では、この Y-Z 平面内で各面の偏心を行っており、また、各回転非対称自由曲面の唯一の対称面を Y-Z 面としている。

偏心面については、上記座標系の原点から、その面の面頂位置の偏心量 (X 軸方向、Y 軸方向、Z 軸方向をそれぞれ X, Y, Z) と、その面の中心軸 (自由曲面については、前記 (a) 式の Z 軸、非球面については、後記 (d) 式の Z 軸) の X 軸、Y 軸、Z 軸それぞれを中心とする傾き角 (それぞれ α , β , γ ($^{\circ}$))

とが与えられている。なお、その場合、 α と β の正はそれぞれの軸の正方向に対して反時計回りを、 γ の正はZ軸の正方向に対して時計回りを意味する。

また、各実施例の光学系を構成する光学作用面の中、特定の面とそれに続く面が共軸光学系を構成する場合に、面間隔が与えられており、その他、媒質の屈折率、アッベ数が慣用法に従って与えられている。

また、本発明で用いられる自由曲面の面の形状は前記（a）式により定義し、その定義式のZ軸が自由曲面の軸となる。

また、非球面は、以下の定義式で与えられる回転対称非球面である。

$$Z = (Y^2 / R) / [1 + \{1 - (1 + K) Y^2 / R^2\}^{1/2}] \\ + A Y^4 + B Y^6 + C Y^8 + D Y^{10} + \dots \dots \dots (d)$$

ただし、Zを光の進行方向を正とした光軸（軸上主光線）とし、Yを光軸と垂直な方向にとる。ここで、Rは近軸曲率半径、Kは円錐定数、A、B、C、D、…はそれぞれ4次、6次、8次、10次の非球面係数である。この定義式のZ軸が回転対称非球面の軸となる。

なお、データの記載されていない自由曲面、非球面に関する項は0である。屈折率については、d線（波長587.56nm）に対するものを表記してある。長さの単位はmmである。

また、自由曲面の他の定義式として、前記の（b）式で与えられるZernike多項式がある。

なお、本発明の実施例では、前記（a）式を用いた自由曲面で面形状が表現されているが、上記（b）式、（c）式を用いても同様の作用効果を得られるのは言うまでもない。

さて、図16（a）に戻り、実施例16の実施例4との大きな違いは、光路振分けプリズム10の点にある。中央の光路振分けプリズム10は、両眼の対称面に対して面对称な形状であり、画像表示素子3の観察者と反対側に位置する第1面11が透過面、その第1面11の両側で観察者と反対側に位置する右光路用透過面の第3面14R、左光路用透過面の第3面14L、さらにそれら第4面14

R、1 4 Lの観察者と反対側に位置する右光路用反射面の第2面1 2 Rと左光路用反射面の第2面1 2 Lの5面からなり、右光路用透過面の第4面1 4 R、左光路用透過面の第4面1 4 Lは、それぞれ左光路用反射面の第3面1 3 L、右光路用反射面の第3面1 3 Rと同一面からなり、その同一面は透過面と全反射面を兼ねている。そして、第1面1 1は両眼の対称面に対して面对称な形状、第4面1 4 Rと1 4 L、第2面1 2 Rと1 2 Lは両眼の対称面に対して面对称な形状である。画像表示素子3は、光路振分けプリズム1 0の第1面1 1に面して、光路振分けプリズム1 0の観察者側に配置される。

上記の構成において、左右の光路は両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けプリズム1 0の第1面1 1に入射し、その右光路用反射面の第2面1 2 Rに入射して反射され、次いで左光路用透過面1 4 Lを兼ねる右光路用反射面の第3面1 3 Rに入射して反射され、右光路用透過面1 4 Rを透過して、偏心プリズム体2 Rに入射する。入射光は第1面2 1 Rを透過してプリズム内に入射し、第2面2 2 Rに臨界角以上の入射角で入射して全反射され、第3面2 3 Rに入射して裏面反射され、第4面2 4 Rに臨界角以下の入射角で入射して屈折されて偏心プリズム体2 Rから射出し、右眼用の射出瞳4 Rへ導かれ、観察者の右眼に画像表示素子3の拡大像を投影する。この場合に、画像表示素子3から射出瞳4 Rへ到る光路中に1回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

図1 7の実施例1 7は、図1の実施例1と同様であるが、中央の光路振分けミラー1の構成が異なる。この実施例の場合は、両眼の対称面に対して面对称な形状の右光路用反射面1 Rと左光路用反射面1 Lはそれぞれレンズ8 R、8 Lの裏面にコートされた裏面鏡からなる。その他は同様である。

この構成において、左右の光路は両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の1枚の画像表示素子3からの表示光は、まず、光路振分けミラー1の右光路用レンズ8 Rの入射面1 1 Lから入射し、反

射面 1 R で反射され、再び入射面 1 1 L から射出し、偏心プリズム体 2 R に入射する。入射光は第 1 面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。なお、画像表示素子 3 から射出瞳 4 R へ到る光路中には中間像は結像されない。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

図 1 8 の実施例 1 8 は、図 4 の実施例 4 と同様である。

図 1 9 の実施例 1 9 は、図 5 の実施例 5 と同様である。

図 2 0 の実施例 2 0 は、図 6 の実施例 6 と同様である。

図 2 1 の実施例 2 1 の実施例 6 との大きな違いは、光路振分けプリズム 1 0 の点にある。中央の光路振分けプリズム 1 0 は、両眼の対称面に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 に面していて観察者に面する反射面の右光路用反射面の第 2 面 1 2 R と左光路用反射面の第 2 面 1 2 L、第 1 面 1 1 の観察者側両側に配置された右光路用反射面の第 3 面 1 3 R と左光路用反射面の第 3 面 1 3 L、第 3 面 1 3 R、1 3 L と第 2 面 1 2 R、1 2 L の間の両側に配置された左光路用透過面の第 4 面 1 4 L、右光路用透過面の第 4 面 1 4 R の 7 面からなる。第 1 面 1 1 は両眼の対称面に対して面对称な形状、第 2 面 1 2 R と 1 2 L、第 3 面 1 3 R と 1 3 L、第 4 面 1 4 L と 1 4 R は両眼の対称面に対して面对称な形状である。画像表示素子 3 は、光路振分けプリズム 1 0 の第 1 面 1 1 に面して、光路振分けプリズム 1 0 の観察者とは反対側に配置される。

上記の構成において、左右の光路は両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 1 0 の第 1 面 1 1 に入射し、その右光路用反射面の第 2 面 1 2 R に入射して反射され、次いで第 3 面 1 3 R に入射して反射され、右光路用透過面 1 4 R を透過して、偏心プリズム体 2 R に入射する。入射光は第 1

面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

図 2 2 の実施例 2 2 は、図 2 1 の実施例 2 1 と同様であるが、接眼光学系を構成する右眼用、左眼用の偏心プリズム体 2 R、2 L の射出面 2 4 R、2 4 L と右眼用、左眼用の射出瞳 4 R、4 L の間にそれぞれ接眼レンズ 9 R と 9 L を配置した点で異なる。

図 2 3 の実施例 2 3 は、図 2 の実施例 2 と同様である。

図 2 4 の実施例 2 4 は、図 2 の実施例 2 と同様であるが、負レンズ 5 を接合レンズで構成している点で異なる。

図 2 5 の実施例 2 5 の実施例 1 との大きな違いは、中央の光路振分けミラー 1 が、両眼の対称面に対して面对称な形状の右光路用反射面 1 R と左光路用反射面 1 L に加えて、それらに面する第 2 の右光路用反射面 1 R' と第 2 の左光路用反射面 1 L' との 4 面の反射面からなり、第 2 の反射面 1 R' と 1 L' は両眼の対称面に対して面对称な形状であり、かつ、画像表示素子 3 は、光路振分けミラー 1 の観察者と反対側に配置される点にある。

上記の構成において、左右の光路は両眼の対称面に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けミラー 1 の右光路用反射面 1 R に入射して反射され、次いで第 2 の右光路用反射面 1 R' に入射して反射され、偏心プリズム体 2 R に入射する。入射光は第 1 面 2 1 R を透過してプリズム内に入射し、第 2 面 2 2 R に臨界角以上の入射角で入射して全反射され、第 3 面 2 3 R に入射して裏面反射され、第 4 面 2 4 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大

像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面对称な関係になる。

図 2 6 の実施例 2 6 は、図 1 1 の実施例 1 1 と同様である。

図 2 7 の実施例 2 7 は、図 7 の実施例 7 と同様である。ただし、右眼用、左眼用の接眼光学系を構成する偏心プリズム体 2 L、2 R の第 2 面 2 2 L、2 2 R と第 4 面 2 4 L、2 4 R はそれぞれ同一の反射面からなっている。

図 2 8 の実施例 2 8 は、図 1 2 の実施例 1 2 と同様である。

図 2 9 に、本発明による実施例 2 9 ～ 3 0 の画像表示装置の光路図を示す。図 2 9 において、画像表示素子を構成する画像表示素子を符号 3 で、右眼用の射出瞳を 4 R で、左眼用の射出瞳を 4 L で示し、また、右眼用の光学系で右眼前に配置する偏心プリズム体を 2 R、左眼用の光学系で左眼前に配置する偏心プリズム体を 2 L で示す。さらに、両眼の中央に配置する偏心プリズム体からなる光路振分けプリズムを 1 0 で示す。これらの偏心プリズム体 2 R、2 L、1 0 は屈折率が 1 より大きい透明媒体からなっている。また、下記の説明において、反射面と説明している面は、全反射面以外は偏心プリズム体の対象の面にミラーコートを施してミラー面としたものである。

この実施例 2 9 ～ 3 0 は、図 2 9 に水平断面（Y-Z 断面）を示すような構成になっており、まず、右眼用の光路で説明する。中央の三角柱状の光路振分けプリズム 1 0 は、両眼の対称面（右眼用射出瞳 4 R と左眼用射出瞳 4 L の中心間を結んだ線分の中心を通りその線分に垂直な平面）2 0 に対して面对称な形状であり、画像表示素子 3 の観察者側に位置する第 1 面 1 1 が透過面、その第 1 面 1 1 の両側で観察者側に位置する全反射面として作用する右光路用反射面の第 2 面 1 2 R と左光路用反射面の第 2 面 1 2 L、右光路用反射面の第 2 面 1 2 R と同一面の左光路用透過面 1 3 L、左光路用反射面の第 2 面 1 2 L と同一面の右光路用透過面 1 3 R の 3 面からなる。第 1 面 1 1 は両眼の対称面 2 0 に対して面对称な形状、第 2 面 1 2 R（1 3 L）と 1 2 L（1 3 R）は両眼の対称面 2 0 に対して面对称な形状である。画像表示素子 3 は、光路振分けプリズム 1 0 の第 1 面 1 1 に

面して、光路振分けプリズム 10 の観察者とは反対側に配置される。

右眼用の光学系を構成する偏心プリズム体 2 R と左眼用の光学系を構成する偏心プリズム体 2 L とは同一形状のもので、両眼の対称面 20 に対して面对称に配置され、それぞれ光線が通る順番で、第 1 面 21 R (21 L)、第 2 面 22 R (22 L)、第 3 面 23 R (23 L)、第 4 面 24 R (24 L) から構成されており、第 2 面 22 R (22 L) と第 4 面 24 R (24 L) は同一面からなり、その同一面は全反射面と透過面を兼ねている。

上記の構成において、左右の光路は両眼の対称面 20 に対して面对称であるので、右眼用の光路を代表的に説明する。共通の 1 枚の画像表示素子 3 からの表示光は、まず、光路振分けプリズム 10 の第 1 面 11 に入射し、その右光路用反射面の第 2 面 12 R に入射して全反射され、右光路用透過面 13 R (12 L) を透過して、偏心プリズム体 2 R に入射する。入射光は第 1 面 21 R を透過してプリズム内に入射し、第 2 面 22 R に臨界角以上の入射角で入射して全反射され、第 3 面 23 R に入射して裏面反射され、第 4 面 24 R に臨界角以下の入射角で入射して屈折されて偏心プリズム体 2 R から射出し、右眼用の射出瞳 4 R へ導かれ、観察者の右眼に画像表示素子 3 の拡大像を投影する。この場合に、画像表示素子 3 から射出瞳 4 R へ到る光路中に 1 回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面 20 を挟んで、右眼用の光路と面对称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子 3 からの表示光は、3 回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも 1 面が正パワーを有する反射面及び透過面を経て画像表示素子 3 の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。

さらに、左右何れの光路も大部分、屈折率が 1 より大きい透明媒体で満たされた偏心プリズム体 10、2 R、2 L 中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。

また、偏心プリズム体 2 R、2 L は面对称な位置に配置されるが、その形状は同一なものである、同じ形状の 2 つの偏心プリズム体 2 R、2 L を用意し、中央の偏心プリズム体 1 0 に対して面对称な位置に配置すればよい。

以上のような光学系には、視野角特性の広い画像表示素子 3 を使うことが前提となる。そのため、画像表示素子 3 には、自家発光タイプの有機 E L (図 4 0 参照) を用いるのが望ましい。また、透過型 L C D (液晶表示素子) を用いる場合には、L C D とバックライトの間に D O E (回折光学素子) を入れて、±1 次光で照明すること、あるいは、視野角が大きくなるような散乱フィルムを使うことで、視野角特性を広くした L C D を使うことが望ましい (実施例 1 ~ 3 0 においても同様である。))。

ところで、図 3 0 に示すように、画像表示素子 3 の表示画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズム 1 0 の第 2 面 1 2 R と 1 2 L の表示光の反射時における角度 α (本発明の画像表示装置では、右眼の光路と左眼の光路は面对称な関係にあるので、図 3 0 では、簡単のため、右眼用光路のみを示してある。) は、

$$33^{\circ} \leq \alpha \leq 70^{\circ} \quad \dots (1)$$

となる条件を満たすことが望ましい。この条件式の下限の 33° を下回る場合は、光線が第 2 面 1 2 R と 1 2 L で反射せずに透過してしまい、像を形成しない。上限の 70° を上回る場合は、この光学系の構成で前述の光路を通ることは難しく、像を形成しなくなる。

さらに好ましくは、

$$40^{\circ} \leq \alpha \leq 60^{\circ} \quad \dots (1-1)$$

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式 (1) と同様である。

次に、図 3 0 に示すように、右眼用射出瞳 4 R と左眼用射出瞳 4 L の中心間を結んだ線分の中心を通りその線分に垂直な平面 2 0 (両眼の対称面) と、光路振分けプリズム 1 0 の第 2 面 1 2 R に右眼用光路の光軸が入射する点における第 2 面 1 2 R の接平面 1 5 とがなす角 β 、及び、平面 2 0 と光路振分けプリズム 1 0

の第2面12Lに左眼用光路の光軸が入射する点における第2面12Lの接平面とがなす角 β は、

$$13^\circ \leq \beta \leq 24^\circ \quad \dots (2)$$

となる条件を満たすことが望ましい。この条件式の下限の 13° を下回る場合は、一部の光線が反射後の第3面13Rで透過せずに反射したり、偏心プリズム体2Rの第2面22Rを反射せずに透過してしまい、前述の光路を通ることは難しく、像を形成しなくなる。上限の 24° を上回る場合は、一部の光線が第2面12Rで反射せずに透過してしまい、前述の光路を通ることは難しく、像を形成しなくなる。

さらに好ましくは、

$$15^\circ \leq \beta \leq 22^\circ \quad \dots (2-1)$$

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式(2)と同様である。

さらに好ましくは、

$$17^\circ \leq \beta \leq 20^\circ \quad \dots (2-2)$$

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式(2)と同様である。

次に、瞳側から逆光線追跡した場合に、右眼用射出瞳4R中心を通る右側最大画角の光線と右眼用の偏心プリズム体2Rの第4面24Rとが交わる点と、左眼用射出瞳4L中心を通る左側最大画角の光線と左眼用の偏心プリズム体2Lの第4面24Lとが交わる点との間隔を、図31に示すように、横幅Lとし、また、左右の射出瞳中心を通る全画角内の光線束の中、右眼ER用の偏心プリズム体2Rあるいは左眼EL用の偏心プリズム体2Lの第4面24R、24Lを透過あるいは反射する点の中で最も左右の射出瞳側に近い点と、画像表示素子3の表示面とのその表示面に垂直な方向の距離を奥行Dとした場合、この横幅Lと奥行Dとの比 D/L が、

$$0.3 \leq D/L \leq 0.5 \quad \dots (3)$$

となる条件を満たすことが望ましい。下限の 0.3 を下回る場合は、広い画角が

取れなくなり、画面が小さくなってしまう。上限の 0.5 を上回る場合は、奥行が大きくなり、光学系が大型化してしまう。

さらに好ましくは、

$$0.35 \leq D/L \leq 0.45 \quad \dots (3-1)$$

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式 (3) と同様である。

上記のように、実施例 29、30 では、右眼用の光学系光路と左眼用の光学系光路は面对称な関係にあるので、図 32、図 33 にそれぞれ上記実施例 29、30 の右眼用の光学系のみを示す水平断面図を示す。左眼用の光学系については、両眼の対称面 20 (図 29) に対して、面对称の関係となるように、左眼用の光学系の面を配置すればよい。

以下に上記実施例 16～30 の逆光線追跡での右眼用光学系の構成パラメータを示す。これらの実施例は、観察光学系とした場合に、実施例 16～21、23～28 の観察画角は、水平半画角 10° 、垂直半画角 7.5° 、実施例 22 の観察画角は、水平半画角 12° 、垂直半画角 9.1° であり、実施例 29 の観察画角は、水平半画角 7° 、垂直半画角 5.26° であり、実施例 30 の観察画角は、水平半画角 7.5° 、垂直半画角 5.64° である。また、実施例 16～28 において、画像表示素子の大きさは、 $8.9 \times 6.7 \text{ mm}$ であり、実施例 29 においては、 $8.94 \times 6.71 \text{ mm}$ であり、実施例 30 においては、 $8.94 \times 6.71 \text{ mm}$ である。瞳径は、実施例 16～30 全てにおいて、 4 mm である。なお、実施例 29 は、観察光学系とした場合に、焦点距離 36 mm に相当し、実施例 30 は、焦点距離 34 mm に相当する。

なお、以下の表中の“F F S”は自由曲面、“A S S”は非球面、“R E”は反射面をそれぞれ示す。

Example 16

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
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Object	∞	-1000.00			
plane					
1	∞ (Stop)				
2	A S S ①	(1)	1.5254	56.2	
3	F F S ① (R E)	(2)	1.5254	56.2	
4	A S S ① (R E)	(1)	1.5254	56.2	
5	F F S ②	(3)			
6	F F S ③	(4)	1.5254	56.2	
7	F F S ④ (R E)	(5)	1.5254	56.2	
8	F F S ⑤ (R E)	(6)	1.5254	56.2	
9	∞	(7)			
Image	∞	(8)			
plane					

A S S ①

R	-61.00
K	0.0000
A	-2.8485×10^{-6}
B	8.9070×10^{-9}

F F S ①

C_4	-1.2212×10^{-2}	C_6	-1.2499×10^{-2}	C_8	-7.2115×10^{-6}
C_{10}	3.6893×10^{-5}	C_{11}	-2.8593×10^{-6}	C_{13}	-3.0073×10^{-6}
C_{15}	-3.4462×10^{-6}	C_{17}	-1.6344×10^{-9}	C_{19}	-4.1364×10^{-8}
C_{21}	-2.0345×10^{-8}				

F F S ②

C_4	1.0330×10^{-2}	C_6	-2.2053×10^{-2}	C_8	-8.5243×10^{-5}
C_{10}	-1.3497×10^{-3}	C_{11}	1.1148×10^{-4}	C_{13}	-2.6040×10^{-4}
C_{15}	3.9230×10^{-4}				

F F S ③

$$\begin{array}{lll}
C_4 & -8.5360 \times 10^{-3} & C_6 & -8.8071 \times 10^{-3} & C_8 & 7.1801 \times 10^{-5} \\
C_{10} & 7.6086 \times 10^{-5} & C_{11} & 6.3213 \times 10^{-7} & C_{13} & 8.2333 \times 10^{-6} \\
C_{15} & 1.9455 \times 10^{-6} & & & &
\end{array}$$

F F S ④

$$\begin{array}{lll}
C_4 & 8.5360 \times 10^{-3} & C_6 & 8.8071 \times 10^{-3} & C_8 & -7.1801 \times 10^{-5} \\
C_{10} & -7.6086 \times 10^{-5} & C_{11} & -6.3213 \times 10^{-7} & C_{13} & -8.2333 \times 10^{-6} \\
C_{15} & -1.9455 \times 10^{-6} & & & &
\end{array}$$

F F S ⑤

$$\begin{array}{lll}
C_4 & 1.2329 \times 10^{-2} & C_6 & 6.7124 \times 10^{-3} & C_8 & -3.9501 \times 10^{-5} \\
C_{10} & -1.3809 \times 10^{-4} & C_{11} & -1.6628 \times 10^{-6} & C_{13} & 3.6302 \times 10^{-6} \\
C_{15} & -3.8832 \times 10^{-6} & & & &
\end{array}$$

Displacement and tilt(1)

$$\begin{array}{llll}
X & 0.00 & Y & 9.84 & Z & 32.73 \\
\alpha & -0.88 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(2)

$$\begin{array}{llll}
X & 0.00 & Y & -0.48 & Z & 39.28 \\
\alpha & -30.61 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(3)

$$\begin{array}{llll}
X & 0.00 & Y & 16.17 & Z & 37.03 \\
\alpha & 35.52 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(4)

$$\begin{array}{llll}
X & 0.00 & Y & 19.39 & Z & 46.79 \\
\alpha & -91.71 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(5)

$$\begin{array}{llll}
X & 0.00 & Y & 44.61 & Z & 46.79 \\
\alpha & -88.29 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(6)

$$\begin{array}{llll}
X & 0.00 & Y & 22.62 & Z & 55.56
\end{array}$$

α 136.79 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 33.76

α -180.00 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 32.00 Z 29.64

α -180.00 β 0.00 γ 0.00

Example 1 7

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)		1.5254	56.2
3	F F S ① (R E)	(2)		1.5254	56.2
4	A S S ① (R E)	(1)		1.5254	56.2
5	F F S ②	(3)			
6	F F S ③	(4)		1.5254	56.2
7	F F S ④ (R E)	(5)		1.5254	56.2
8	F F S ③	(4)			
Image plane	∞	(6)			
	A S S ①				
R	-95.45				
K	0.0000				
A	-6.5740×10^{-8}				
B	1.3849×10^{-9}				

F F S ①

C_4	-1.0306×10^{-2}	C_6	-1.0412×10^{-2}	C_8	2.0096×10^{-5}
C_{10}	2.8787×10^{-5}	C_{11}	-7.7967×10^{-7}	C_{13}	-2.3996×10^{-6}
C_{15}	-2.6208×10^{-6}	C_{17}	-6.0108×10^{-8}	C_{19}	1.1907×10^{-8}
C_{21}	1.4876×10^{-8}				

F F S ②

C_4	-7.5538×10^{-3}	C_6	6.2696×10^{-4}	C_8	1.3858×10^{-3}
C_{10}	2.0287×10^{-3}	C_{11}	8.0303×10^{-5}	C_{13}	-1.5350×10^{-4}
C_{15}	-6.5070×10^{-5}				

F F S ③

C_4	-7.6923×10^{-2}	C_6	-9.3217×10^{-3}	C_8	3.8760×10^{-3}
C_{10}	-9.4736×10^{-4}	C_{11}	-7.2844×10^{-4}	C_{13}	6.5675×10^{-4}
C_{15}	-4.9359×10^{-5}				

F F S ④

C_4	-1.1587×10^{-2}	C_6	1.1772×10^{-2}	C_8	1.0849×10^{-3}
C_{10}	-1.8206×10^{-4}	C_{11}	-5.4651×10^{-4}	C_{13}	1.7195×10^{-4}
C_{15}	-1.3202×10^{-5}				

Displacement and tilt(1)

X	0.00	Y	9.05	Z	39.11
α	10.70	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	0.24	Z	48.07
α	-21.35	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	19.03	Z	43.57
α	92.98	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	35.65	Z	58.02
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α -145.94 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 39.28 Z 61.80

α -147.29 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 38.00

α 0.00 β 0.00 γ 0.00

Example 1 8

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S①	(1)	1.5254	56.2	
3	F F S① (R E)	(2)	1.5254	56.2	
4	A S S① (R E)	(1)	1.5254	56.2	
5	F F S②	(3)			
6	F F S③	(4)	1.5254	56.2	
7	F F S④ (R E)	(5)	1.5254	56.2	
8	F F S⑤	(6)			
Image plane	∞	(7)			
	A S S①				
R	-99.17				
K	0.0000				
A	-5.1344×10^{-6}				
B	5.4560×10^{-9}				

F F S ①

C_4	-1.3402×10^{-2}	C_6	-1.1018×10^{-2}	C_8	2.9828×10^{-6}
C_{10}	-4.6829×10^{-6}	C_{11}	-2.4079×10^{-6}	C_{13}	-3.1115×10^{-6}
C_{15}	-2.2505×10^{-6}	C_{17}	1.0452×10^{-7}	C_{19}	1.1084×10^{-7}
C_{21}	2.6833×10^{-8}				

F F S ②

C_4	-1.9489×10^{-2}	C_6	-3.8808×10^{-3}	C_8	4.8522×10^{-3}
C_{10}	4.8858×10^{-3}	C_{11}	1.8575×10^{-4}	C_{13}	-7.7300×10^{-4}
C_{15}	-6.0291×10^{-4}				

F F S ③

C_4	-8.6443×10^{-2}	C_6	-3.9460×10^{-2}	C_8	8.0248×10^{-3}
C_{10}	9.1640×10^{-3}	C_{11}	-6.2318×10^{-5}	C_{13}	1.4493×10^{-3}
C_{15}	1.6706×10^{-3}				

F F S ④

C_4	1.9984×10^{-2}	C_6	1.7719×10^{-2}	C_8	2.2720×10^{-4}
C_{10}	2.2345×10^{-4}	C_{11}	6.1407×10^{-6}	C_{13}	2.3412×10^{-5}
C_{15}	-1.4916×10^{-6}				

F F S ⑤

C_4	-1.0029×10^{-2}	C_6	4.6836×10^{-3}
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Displacement and tilt(1)

X	0.00	Y	12.74	Z	36.00
α	2.52	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.37	Z	45.03
α	-28.87	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	20.71	Z	40.51
α	74.60	β	0.00	γ	0.00

Displacement and tilt(4)

X 0.00 Y 22.61 Z 41.95
 α -113.38 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 38.54 Z 52.07
 α -144.30 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 36.77
 α 0.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 30.00
 α 0.00 β 0.00 γ 0.00

Example 19

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S①	(1)	1.5254	56.2	
3	F F S① (R E)	(2)	1.5254	56.2	
4	A S S① (R E)	(1)	1.5254	56.2	
5	F F S②	(3)			
6	F F S③	(4)	1.5254	56.2	
7	F F S④ (R E)	(5)	1.5254	56.2	
8	F F S⑤	(6)			
Image plane	∞	(7)			

A S S ①

R	371.46
K	0.0000
A	-8.4688×10^{-7}
B	2.9089×10^{-10}

F F S ①

C_4	-6.3820×10^{-3}	C_6	-8.9287×10^{-3}	C_8	-7.5189×10^{-5}
C_{10}	-2.7485×10^{-6}	C_{11}	-5.1745×10^{-6}	C_{13}	-6.0033×10^{-7}
C_{15}	2.8823×10^{-6}	C_{17}	3.2184×10^{-7}	C_{19}	8.6382×10^{-8}
C_{21}	-1.5498×10^{-8}				

F F S ②

C_4	-4.0226×10^{-2}	C_6	-3.3297×10^{-2}	C_8	2.4201×10^{-3}
C_{10}	6.0781×10^{-3}	C_{11}	7.4789×10^{-4}	C_{13}	-3.2635×10^{-4}
C_{15}	2.1572×10^{-4}				

F F S ③

C_4	-2.0127×10^{-2}	C_6	-1.4009×10^{-2}	C_8	-1.3093×10^{-3}
C_{10}	-1.0645×10^{-4}	C_{11}	-2.3099×10^{-4}	C_{13}	-2.8818×10^{-5}
C_{15}	-1.4532×10^{-6}				

F F S ④

C_4	2.0127×10^{-2}	C_6	1.4009×10^{-2}	C_8	1.3093×10^{-3}
C_{10}	1.0645×10^{-4}	C_{11}	2.3099×10^{-4}	C_{13}	2.8818×10^{-5}
C_{15}	1.4532×10^{-6}				

F F S ⑤

C_4	2.3952×10^{-1}	C_6	6.3371×10^{-4}
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Displacement and tilt(1)

X	0.00	Y	20.12	Z	35.02
α	6.83	β	0.00	γ	0.00

Displacement and tilt(2)

X 0.00 Y 0.52 Z 47.68
 α -27.07 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 27.52 Z 37.59
 α 76.08 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 29.00 Z 40.96
 α -118.18 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 35.00 Z 40.96
 α -61.82 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 50.73
 α -180.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 58.00
 α -180.00 β 0.00 γ 0.00

Example 2 0

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)		1.5254	56.2
3	F F S ① (R E)	(2)		1.5254	56.2
4	A S S ① (R E)	(1)		1.5254	56.2
5	F F S ②	(3)			

6	F F S ③	(4)	1.5254	56.2
7	F F S ④ (R E)	(5)	1.5254	56.2
8	F F S ⑤ (R E)	(6)	1.5254	56.2
9	F F S ⑥	(7)		
Image plane	∞	(8)		

A S S ①

R	-78.87
K	0.0000
A	6.3888×10^{-6}
B	-6.7614×10^{-9}

F F S ①

C_4	-1.3820×10^{-2}	C_6	-1.2744×10^{-2}	C_8	-5.9146×10^{-5}
C_{10}	-8.6079×10^{-5}	C_{11}	-1.5009×10^{-6}	C_{13}	-3.9389×10^{-6}
C_{15}	-3.9837×10^{-6}	C_{17}	9.5456×10^{-8}	C_{19}	2.5646×10^{-7}
C_{21}	8.4257×10^{-8}				

F F S ②

C_4	-4.8112×10^{-2}	C_6	2.2437×10^{-2}	C_8	1.2629×10^{-2}
C_{10}	-1.4147×10^{-3}	C_{11}	1.1201×10^{-3}	C_{13}	-4.2802×10^{-3}
C_{15}	-1.8265×10^{-5}				

F F S ③

C_4	-2.4894×10^{-2}	C_6	1.7719×10^{-3}	C_8	1.3030×10^{-2}
C_{10}	8.7223×10^{-3}	C_{11}	-2.5693×10^{-3}	C_{13}	2.0937×10^{-3}
C_{15}	-1.7955×10^{-4}				

F F S ④

C_4	1.4510×10^{-2}	C_6	1.4974×10^{-2}	C_8	6.3447×10^{-5}
C_{10}	-3.3021×10^{-5}	C_{11}	6.7340×10^{-6}	C_{13}	1.3268×10^{-5}
C_{15}	5.6476×10^{-6}				

F F S ⑤

$$\begin{array}{lll} C_4 & -5.0177 \times 10^{-3} & C_6 \quad 4.2398 \times 10^{-3} \quad C_{11} \quad 1.3297 \times 10^{-5} \\ C_{13} & 1.7182 \times 10^{-5} & C_{15} \quad 7.8122 \times 10^{-6} \end{array}$$

F F S ⑥

$$\begin{array}{lll} C_4 & 6.6144 \times 10^{-2} & C_6 \quad 3.1372 \times 10^{-2} \quad C_{11} \quad 5.4070 \times 10^{-4} \\ C_{13} & -2.1336 \times 10^{-4} & C_{15} \quad -4.3706 \times 10^{-4} \end{array}$$

Displacement and tilt(1)

$$\begin{array}{llll} X & 0.00 & Y & 13.06 & Z & 30.44 \\ \alpha & 4.48 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(2)

$$\begin{array}{llll} X & 0.00 & Y & -0.13 & Z & 38.51 \\ \alpha & -29.74 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(3)

$$\begin{array}{llll} X & 0.00 & Y & 17.85 & Z & 32.43 \\ \alpha & 74.33 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(4)

$$\begin{array}{llll} X & 0.00 & Y & 19.17 & Z & 33.07 \\ \alpha & -102.30 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(5)

$$\begin{array}{llll} X & 0.00 & Y & 44.66 & Z & 43.01 \\ \alpha & -133.87 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(6)

$$\begin{array}{llll} X & 0.00 & Y & 32.00 & Z & 30.30 \\ \alpha & -180.00 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(7)

$$\begin{array}{llll} X & 0.00 & Y & 32.00 & Z & 48.57 \\ \alpha & 0.00 & \beta & 0.00 & \gamma & 0.00 \end{array}$$

Displacement and tilt(8)

X 0.00 Y 32.00 Z 53.57
 α 0.00 β 0.00 γ 0.00

Example 2 1

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)		(1)		
2	A S S ①		(2)	1.5254	56.2
3	F F S ① (R E)		(3)	1.5254	56.2
4	A S S ① (R E)		(2)	1.5254	56.2
5	F F S ②		(4)		
6	F F S ③		(5)	1.5254	56.2
7	F F S ④ (R E)		(6)	1.5254	56.2
8	F F S ⑤ (R E)		(7)	1.5254	56.2
9	F F S ⑥		(8)		
Image plane	∞		(9)		

A S S ①

R -93.13

K 0.0000

A -7.3153×10^{-6} B 1.0465×10^{-8}

F F S ①

C₄ -1.2530×10^{-2} C₆ -1.0935×10^{-2} C₈ 4.3572×10^{-5} C₁₀ 5.6790×10^{-5} C₁₁ -4.6759×10^{-6} C₁₃ -5.7024×10^{-6} C₁₅ -2.5865×10^{-6} C₁₇ 5.1708×10^{-8} C₁₉ 4.7739×10^{-8}

$$C_{21} \quad 4.8274 \times 10^{-8}$$

F F S ②

$$C_4 \quad 2.1276 \times 10^{-2} \quad C_6 \quad -1.3001 \times 10^{-2} \quad C_8 \quad 1.2698 \times 10^{-2}$$

$$C_{10} \quad -4.0940 \times 10^{-3} \quad C_{11} \quad 6.8259 \times 10^{-4} \quad C_{13} \quad -1.1193 \times 10^{-3}$$

$$C_{15} \quad -4.9525 \times 10^{-5}$$

F F S ③

$$C_4 \quad -7.7818 \times 10^{-2} \quad C_6 \quad -1.3978 \times 10^{-2} \quad C_8 \quad 8.2943 \times 10^{-3}$$

$$C_{10} \quad -3.6125 \times 10^{-3} \quad C_{11} \quad -2.1473 \times 10^{-3} \quad C_{13} \quad 1.6422 \times 10^{-3}$$

$$C_{15} \quad 2.1472 \times 10^{-4}$$

F F S ④

$$C_4 \quad 1.7708 \times 10^{-2} \quad C_6 \quad 9.8479 \times 10^{-3} \quad C_8 \quad 4.2747 \times 10^{-5}$$

$$C_{10} \quad 1.4710 \times 10^{-6} \quad C_{11} \quad 6.0476 \times 10^{-6} \quad C_{13} \quad 9.5455 \times 10^{-6}$$

$$C_{15} \quad 7.9647 \times 10^{-6}$$

F F S ⑤

$$C_4 \quad -3.2083 \times 10^{-3} \quad C_6 \quad -1.1682 \times 10^{-2} \quad C_8 \quad -3.8379 \times 10^{-4}$$

$$C_{10} \quad -4.7983 \times 10^{-4} \quad C_{11} \quad 3.2203 \times 10^{-5} \quad C_{13} \quad 2.4146 \times 10^{-5}$$

$$C_{15} \quad 1.5623 \times 10^{-5}$$

F F S ⑥

$$C_4 \quad -1.2690 \times 10^{-2} \quad C_6 \quad 1.2046 \times 10^{-2}$$

Displacement and tilt(1)

$$X \quad 0.00 \quad Y \quad 0.00 \quad Z \quad 0.00$$

$$\alpha \quad 0.00 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(2)

$$X \quad 0.00 \quad Y \quad 11.12 \quad Z \quad 31.05$$

$$\alpha \quad 6.41 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(3)

$$X \quad 0.00 \quad Y \quad -0.11 \quad Z \quad 39.90$$

$$\alpha \quad -26.24 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(4)

X 0.00 Y 19.37 Z 34.98
 α 52.37 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 19.70 Z 35.09
 α -124.03 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 41.67 Z 44.93
 α -137.82 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 36.67 Z 30.00
 α -176.69 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 32.00 Z 48.79
 α 0.00 β 0.00 γ 0.00

Displacement and tilt(9)

X 0.00 Y 32.00 Z 51.01
 α 0.00 β 0.00 γ 0.00

Example 2 2

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)		(1)		
2	∞		(2)	1.4924	107.9
3	A S S ①		(3)		
4	A S S ②		(4)	1.5254	56.2

5	F F S ① (R E)	(5)	1. 5254	56. 2
6	A S S ② (R E)	(4)	1. 5254	56. 2
7	F F S ②	(6)		
8	F F S ③	(7)	1. 5254	56. 2
9	F F S ④ (R E)	(8)	1. 5254	56. 2
10	F F S ⑤ (R E)	(9)	1. 5254	56. 2
11	F F S ⑥	(10)		
Image	∞	(11)		
plane				

A S S ①

R -31. 17

K 0. 0000

A $-2. 3392 \times 10^{-6}$ B $1. 4417 \times 10^{-8}$

A S S ②

R -104. 32

K 0. 0000

A $-1. 1160 \times 10^{-5}$ B $1. 3866 \times 10^{-8}$

F F S ①

C₄ $-1. 1076 \times 10^{-2}$ C₆ $-9. 7026 \times 10^{-3}$ C₈ $1. 2453 \times 10^{-4}$ C₁₀ $8. 6331 \times 10^{-5}$

F F S ②

C₄ $-2. 6908 \times 10^{-2}$ C₆ $-2. 2030 \times 10^{-2}$ C₈ $3. 0544 \times 10^{-3}$ C₁₀ $-2. 0443 \times 10^{-3}$

F F S ③

C₄ $-4. 7273 \times 10^{-2}$ C₆ $-2. 9318 \times 10^{-2}$ C₈ $4. 8533 \times 10^{-4}$ C₁₀ $-2. 1511 \times 10^{-3}$

F F S ④

$$\begin{array}{llll}
 C_4 & 1.3337 \times 10^{-2} & C_6 & 7.7917 \times 10^{-3} \\
 C_8 & 5.2903 \times 10^{-6} & & \\
 C_{10} & 3.2236 \times 10^{-5} & &
 \end{array}$$

F F S ⑤

$$\begin{array}{llll}
 C_4 & -7.4443 \times 10^{-3} & C_6 & -1.1004 \times 10^{-2} \\
 C_8 & -3.4435 \times 10^{-4} & & \\
 C_{10} & -2.7416 \times 10^{-4} & &
 \end{array}$$

F F S ⑥

$$\begin{array}{ll}
 C_4 & 8.1792 \times 10^{-3} \\
 C_6 & 7.4722 \times 10^{-3}
 \end{array}$$

Displacement and tilt(1)

$$\begin{array}{llll}
 X & 0.00 & Y & 0.00 \\
 \alpha & 0.00 & \beta & 0.00
 \end{array}$$

Displacement and tilt(2)

$$\begin{array}{llll}
 X & 0.00 & Y & 0.00 \\
 \alpha & 0.00 & \beta & 0.00
 \end{array}$$

Displacement and tilt(3)

$$\begin{array}{llll}
 X & 0.00 & Y & 0.00 \\
 \alpha & 0.00 & \beta & 0.00
 \end{array}$$

Displacement and tilt(4)

$$\begin{array}{llll}
 X & 0.00 & Y & 10.49 \\
 \alpha & 6.19 & \beta & 0.00
 \end{array}$$

Displacement and tilt(5)

$$\begin{array}{llll}
 X & 0.00 & Y & -0.10 \\
 \alpha & -24.76 & \beta & 0.00
 \end{array}$$

Displacement and tilt(6)

$$\begin{array}{llll}
 X & 0.00 & Y & 18.51 \\
 \alpha & 55.35 & \beta & 0.00
 \end{array}$$

Displacement and tilt(7)

$$\begin{array}{llll}
 X & 0.00 & Y & 19.05 \\
 Z & 35.60 & &
 \end{array}$$

α -111.46 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 41.39 Z 45.63

α -142.01 β 0.00 γ 0.00

Displacement and tilt(9)

X 0.00 Y 38.56 Z 29.81

α 177.05 β 0.00 γ 0.00

Displacement and tilt(10)

X 0.00 Y 32.00 Z 49.26

α 0.00 β 0.00 γ 0.00

Displacement and tilt(11)

X 0.00 Y 32.00 Z 51.37

α 0.00 β 0.00 γ 0.00

Example 2 3

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)	1.5254	56.2	
3	F F S ① (R E)	(2)	1.5254	56.2	
4	A S S ① (R E)	(1)	1.5254	56.2	
5	F F S ②	(3)			
6	F F S ③ (R E)	(4)			
7	9.36	(5)	1.5254	56.2	
8	A S S ②	(6)			
Image	∞	(7)			

plane

A S S ①

R -112.57

K 0.0000

A 1.2804×10^{-7} B 1.9023×10^{-9}

A S S ②

R 17.18

K 0.0000

A -1.1585×10^{-4} B 4.5485×10^{-6}

F F S ①

C₄ -1.0758×10^{-2} C₆ -1.0721×10^{-2} C₈ 7.6154×10^{-5} C₁₀ -1.9106×10^{-5} C₁₁ 4.9749×10^{-6} C₁₃ -5.3415×10^{-6} C₁₅ -2.8610×10^{-6} C₁₇ 1.3623×10^{-7} C₁₉ 2.9234×10^{-8} C₂₁ -5.0012×10^{-9}

F F S ②

C₄ -4.2973×10^{-2} C₆ 3.8451×10^{-2} C₈ 3.6896×10^{-3} C₁₀ 5.7252×10^{-3} C₁₁ 1.4826×10^{-4} C₁₃ -1.1264×10^{-3} C₁₅ 4.7888×10^{-4}

F F S ③

C₄ 2.0862×10^{-2} C₆ 1.8162×10^{-2} C₈ 1.4311×10^{-4} C₁₀ -2.1971×10^{-5} C₁₁ 1.3347×10^{-5} C₁₃ 2.3775×10^{-5} C₁₅ 7.6542×10^{-6}

Displacement and tilt(1)

X 0.00 Y 12.30 Z 38.14

 α -1.09 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y -0.33 Z 45.00

α -31.99 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 19.10 Z 42.18

α 78.03 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 39.78 Z 60.30

α -147.16 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 32.00 Z 40.06

α 0.00 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 37.55

α 0.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 31.96

α 0.00 β 0.00 γ 0.00

Example 2 4

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)		1.5254	56.2
3	F F S ① (R E)	(2)		1.5254	56.2
4	A S S ① (R E)	(1)		1.5254	56.2
5	F F S ②	(3)			

6	F F S ③ (R E)	(4)		
7	10.00	(5)	1.7400	45.0
8	-30.00	(6)	1.4875	70.2
9	20.00	(7)		
Image plane	∞	(8)		

A S S ①

R	-755.72
K	0.0000
A	-3.0223×10^{-6}
B	3.6982×10^{-9}

F F S ①

C_4	-1.3291×10^{-2}	C_6	-9.1362×10^{-3}	C_8	1.3010×10^{-5}
C_{10}	-4.7998×10^{-5}	C_{11}	3.8631×10^{-6}	C_{13}	1.2388×10^{-6}
C_{15}	-1.7387×10^{-6}	C_{17}	4.1889×10^{-7}	C_{19}	3.3450×10^{-8}
C_{21}	1.5434×10^{-8}				

F F S ②

C_4	-4.9441×10^{-2}	C_6	5.0481×10^{-2}	C_8	-1.8555×10^{-3}
C_{10}	1.1867×10^{-3}	C_{11}	-1.0276×10^{-3}	C_{13}	2.6209×10^{-3}
C_{15}	1.5800×10^{-4}				

F F S ③

C_4	2.1838×10^{-2}	C_6	2.0822×10^{-2}	C_8	1.5599×10^{-4}
C_{10}	2.2274×10^{-5}	C_{11}	1.7287×10^{-5}	C_{13}	3.1039×10^{-5}
C_{15}	1.7347×10^{-5}				

Displacement and tilt(1)

X	0.00	Y	15.24	Z	38.77
α	2.68	β	0.00	γ	0.00

Displacement and tilt(2)

X 0.00 Y 0.01 Z 47.98

α -29.39 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 22.36 Z 42.21

α 83.11 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 38.88 Z 54.46

α -145.16 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 32.00 Z 34.24

α 0.00 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 33.17

α 0.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 30.48

α 0.00 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 32.00 Z 28.00

α 0.00 β 0.00 γ 0.00

Example 2 5

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)	1.5254	56.2	

3	F F S① (R E)	(2)	1. 5254	56. 2
4	A S S① (R E)	(1)	1. 5254	56. 2
5	F F S②	(3)		
6	F F S③ (R E)	(4)		
7	F F S④ (R E)	(5)		
Image plane	∞	(6)		

A S S①

R -142. 30

K 0. 0000

A $-7. 9459 \times 10^{-6}$ B $4. 5193 \times 10^{-9}$

F F S①

C₄ $-1. 5782 \times 10^{-2}$ C₆ $-9. 2595 \times 10^{-3}$ C₈ $8. 4720 \times 10^{-5}$ C₁₀ $4. 5249 \times 10^{-5}$ C₁₁ $1. 0602 \times 10^{-5}$ C₁₃ $-8. 7497 \times 10^{-6}$ C₁₅ $-4. 4525 \times 10^{-6}$ C₁₇ $-5. 8969 \times 10^{-8}$ C₁₉ $1. 8760 \times 10^{-7}$ C₂₁ $1. 2837 \times 10^{-7}$

F F S②

C₄ $-4. 8446 \times 10^{-2}$ C₆ $-8. 3829 \times 10^{-3}$

F F S③

C₄ $1. 6543 \times 10^{-2}$ C₆ $9. 5400 \times 10^{-3}$ C₈ $-1. 0953 \times 10^{-4}$ C₁₀ $-1. 8587 \times 10^{-5}$ C₁₁ $5. 3062 \times 10^{-6}$ C₁₃ $7. 9992 \times 10^{-6}$ C₁₅ $5. 7816 \times 10^{-6}$

F F S④

C₄ $-4. 2215 \times 10^{-3}$ C₆ $1. 0692 \times 10^{-2}$ C₈ $-3. 6896 \times 10^{-4}$ C₁₀ $-2. 5259 \times 10^{-4}$ C₁₁ $5. 9277 \times 10^{-6}$ C₁₃ $-1. 3516 \times 10^{-5}$ C₁₅ $-7. 8520 \times 10^{-6}$

Displacement and tilt(1)

X 0.00 Y 11.67 Z 32.96

α -1.41 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y -0.45 Z 40.56

α -30.45 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 18.56 Z 37.77

α 33.95 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 43.39 Z 48.16

α -135.03 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 36.28 Z 31.09

α 6.39 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 55.72

α 0.00 β 0.00 γ 0.00

Example 2 6

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	F F S ①	(1)		1.5254	56.2
3	F F S ② (R E)	(2)		1.5254	56.2
4	F F S ③	(3)			
5	F F S ④	(4)		1.5254	56.2

6	F F S ⑤ (R E)	(5)	1.5254	56.2
7	F F S ⑥	(6)		
Image plane	∞	(7)		

F F S ①

C_4	-6.2629×10^{-3}	C_6	3.3796×10^{-4}	C_8	3.9666×10^{-4}
C_{10}	-1.2581×10^{-4}	C_{11}	2.6158×10^{-6}	C_{13}	3.2906×10^{-5}
C_{15}	1.4501×10^{-6}				

F F S ②

C_4	-1.3276×10^{-2}	C_6	-9.4693×10^{-3}	C_8	-8.4725×10^{-5}
C_{10}	-1.3499×10^{-4}	C_{11}	-2.9102×10^{-6}	C_{13}	-2.0112×10^{-6}
C_{15}	-2.4589×10^{-6}	C_{17}	-4.4244×10^{-9}	C_{19}	-4.8328×10^{-8}
C_{21}	-1.8143×10^{-8}				

F F S ③

C_4	-2.1469×10^{-2}	C_6	-3.3694×10^{-2}	C_8	-1.6179×10^{-3}
C_{10}	-3.2678×10^{-3}	C_{11}	-7.9899×10^{-5}	C_{13}	-1.7505×10^{-4}
C_{15}	-3.5647×10^{-4}				

F F S ④

C_4	-1.1648×10^{-1}	C_6	-4.0332×10^{-2}	C_8	-1.1348×10^{-3}
C_{10}	1.9930×10^{-3}	C_{11}	8.3579×10^{-4}	C_{13}	8.0595×10^{-4}
C_{15}	9.9925×10^{-4}				

F F S ⑤

C_4	1.9541×10^{-2}	C_6	1.6255×10^{-2}	C_8	-1.0516×10^{-5}
C_{10}	-5.5991×10^{-5}	C_{11}	4.5526×10^{-6}	C_{13}	1.2743×10^{-5}
C_{15}	3.8394×10^{-6}				

F F S ⑥

C_4	1.9172×10^{-2}	C_6	3.2175×10^{-2}	C_{11}	9.6401×10^{-5}
C_{13}	-2.6951×10^{-5}	C_{15}	-1.6440×10^{-4}		

Displacement and tilt(1)

X	0.00	Y	0.00	Z	32.45
α	-13.66	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-1.36	Z	48.79
α	-33.83	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	12.70	Z	41.59
α	-50.46	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	19.62	Z	39.02
α	-65.04	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	42.00	Z	30.00
α	-44.81	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	45.53
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	53.23
α	0.00	β	0.00	γ	0.00

Example 2 7

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				

2	A S S ①	(1)	1. 5254	56. 2
3	F F S ① (R E)	(2)	1. 5254	56. 2
4	A S S ① (R E)	(1)	1. 5254	56. 2
5	F F S ① (R E)	(2)	1. 5254	56. 2
6	F F S ②	(3)		
7	F F S ③	(4)	1. 5254	56. 2
8	F F S ④ (R E)	(5)	1. 5254	56. 2
9	F F S ⑤	(6)		
Image plane	∞	(7)		

A S S ①

R -109. 37

K 0. 0000

A $2. 7422 \times 10^{-5}$ B $-4. 1869 \times 10^{-8}$

F F S ①

C₄ $-1. 1126 \times 10^{-2}$ C₆ $-1. 0227 \times 10^{-2}$ C₈ $-6. 0588 \times 10^{-5}$ C₁₀ $-3. 0318 \times 10^{-5}$ C₁₁ $7. 9055 \times 10^{-6}$ C₁₃ $1. 1105 \times 10^{-5}$ C₁₅ $1. 0604 \times 10^{-6}$ C₁₇ $2. 8597 \times 10^{-7}$ C₁₉ $1. 5498 \times 10^{-7}$ C₂₁ $1. 4283 \times 10^{-7}$

F F S ②

C₄ $3. 6878 \times 10^{-2}$ C₆ $3. 5702 \times 10^{-2}$ C₈ $-2. 0106 \times 10^{-2}$ C₁₀ $-9. 8201 \times 10^{-3}$ C₁₁ $2. 1010 \times 10^{-3}$ C₁₃ $-1. 9983 \times 10^{-3}$ C₁₅ $9. 8827 \times 10^{-4}$

F F S ③

C₄ $-1. 0254 \times 10^{-1}$ C₆ $-2. 5575 \times 10^{-2}$ C₈ $-2. 0239 \times 10^{-2}$ C₁₀ $-5. 8721 \times 10^{-3}$ C₁₁ $1. 0962 \times 10^{-3}$ C₁₃ $-3. 3381 \times 10^{-3}$ C₁₅ $4. 7815 \times 10^{-4}$

F F S ④

C_4	2.3287×10^{-2}	C_6	1.8127×10^{-2}	C_8	-4.0703×10^{-4}
C_{10}	-2.4676×10^{-4}	C_{11}	1.9470×10^{-5}	C_{13}	3.1178×10^{-5}
C_{15}	-3.0929×10^{-7}				

F F S ⑤

C_4	-1.9980×10^{-2}	C_6	-1.9644×10^{-2}	C_{11}	1.8913×10^{-4}
C_{13}	4.0095×10^{-4}	C_{15}	5.1524×10^{-4}		

Displacement and tilt(1)

X	0.00	Y	6.56	Z	32.12
α	-2.57	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.19	Z	38.74
α	-23.54	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	20.79	Z	39.32
α	-71.99	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	21.54	Z	38.60
α	-84.73	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	36.81	Z	30.00
α	-35.69	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	44.11
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	50.34
α	0.00	β	0.00	γ	0.00

Example 2 8

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	F F S ①	(1)	1.5254	56.2	
3	F F S ② (R E)	(2)	1.5254	56.2	
4	F F S ③ (R E)	(3)	1.5254	56.2	
5	F F S ④	(4)			
6	F F S ⑤	(5)	1.5254	56.2	
7	F F S ⑥ (R E)	(6)	1.5254	56.2	
8	F F S ⑦ (R E)	(7)	1.5254	56.2	
9	F F S ⑧	(8)			
Image plane	∞	(9)			
F F S ①					
C_4	-8.4040×10^{-3}	C_6	-8.5943×10^{-3}		
F F S ②					
C_4	-4.8109×10^{-3}	C_6	-3.4151×10^{-3}	C_8	7.6983×10^{-6}
C_{10}	5.9643×10^{-6}				
F F S ③					
C_4	8.5504×10^{-4}	C_6	2.0899×10^{-3}	C_8	3.9710×10^{-6}
C_{10}	1.2427×10^{-5}				
F F S ④					
C_4	-4.1338×10^{-3}	C_6	4.6863×10^{-3}		
F F S ⑤					

$$C_4 \quad 1.8948 \times 10^{-2} \quad C_6 \quad 7.8112 \times 10^{-3}$$

F F S ⑥

$$C_4 \quad -2.9136 \times 10^{-3} \quad C_6 \quad -2.6792 \times 10^{-3}$$

F F S ⑦

$$C_4 \quad 1.0066 \times 10^{-2} \quad C_6 \quad 1.0913 \times 10^{-2}$$

F F S ⑧

$$C_4 \quad -2.2044 \times 10^{-2} \quad C_6 \quad -1.6909 \times 10^{-2}$$

Displacement and tilt(1)

$$X \quad 0.00 \quad Y \quad 0.00 \quad Z \quad 30.00$$

$$\alpha \quad 0.00 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(2)

$$X \quad 0.00 \quad Y \quad 7.73 \quad Z \quad 66.05$$

$$\alpha \quad 18.69 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(3)

$$X \quad 0.00 \quad Y \quad -17.85 \quad Z \quad 38.62$$

$$\alpha \quad 46.96 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(4)

$$X \quad 0.00 \quad Y \quad 20.71 \quad Z \quad 58.27$$

$$\alpha \quad 70.85 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(5)

$$X \quad 0.00 \quad Y \quad 21.56 \quad Z \quad 58.79$$

$$\alpha \quad 72.18 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(6)

$$X \quad 0.00 \quad Y \quad 41.10 \quad Z \quad 68.55$$

$$\alpha \quad 46.38 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(7)

$$X \quad 0.00 \quad Y \quad 28.64 \quad Z \quad 46.33$$

$$\alpha \quad 17.45 \quad \beta \quad 0.00 \quad \gamma \quad 0.00$$

Displacement and tilt(8)

X 0.00 Y 32.02 Z 71.98
 α 0.00 β 0.00 γ 0.00

Displacement and tilt(9)

X 0.00 Y 32.00 Z 76.97
 α 0.00 β 0.00 γ 0.00

Example 2 9

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
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Object plane	∞	-1000.00			
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1	∞ (Stop)				
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2	A S S ①	(1)	1.5254	56.2	
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3	F F S ① (R E)	(2)	1.5254	56.2	
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4	A S S ① (R E)	(1)	1.5254	56.2	
---	---------------	-----	--------	------	--

5	F F S ②	(3)			
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6	F F S ③	(4)	1.5254	56.2	
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7	F F S ④ (R E)	(5)	1.5254	56.2	
---	---------------	-----	--------	------	--

8	F F S ⑤	(6)			
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Image plane	∞	(7)			
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A S S ①

R 1285.39

K 0.0000

A 6.4599×10^{-7} B -3.7861×10^{-10}

F F S ①

$$\begin{array}{lll}
C_4 & -3.6795 \times 10^{-3} & C_6 & -2.1319 \times 10^{-3} & C_8 & -5.8405 \times 10^{-5} \\
C_{10} & -6.5664 \times 10^{-5} & C_{11} & 8.2431 \times 10^{-7} & C_{13} & 1.4603 \times 10^{-6} \\
C_{15} & 1.4571 \times 10^{-6} & C_{17} & -5.6374 \times 10^{-8} & C_{19} & -3.7292 \times 10^{-8} \\
C_{21} & -4.3730 \times 10^{-8} & & & &
\end{array}$$

F F S ②

$$\begin{array}{lll}
C_4 & -3.1489 \times 10^{-4} & C_6 & 5.2538 \times 10^{-3} & C_8 & 1.2817 \times 10^{-3} \\
C_{10} & 1.2156 \times 10^{-3} & C_{11} & 5.1327 \times 10^{-6} & C_{13} & -1.0362 \times 10^{-5} \\
C_{15} & 4.7618 \times 10^{-5} & & & &
\end{array}$$

F F S ③

$$\begin{array}{lll}
C_4 & -2.2969 \times 10^{-3} & C_6 & -4.7767 \times 10^{-4} & C_8 & 3.1569 \times 10^{-4} \\
C_{10} & 1.9939 \times 10^{-4} & C_{11} & 4.1969 \times 10^{-7} & C_{13} & 1.3660 \times 10^{-5} \\
C_{15} & 4.6817 \times 10^{-6} & & & &
\end{array}$$

F F S ④

$$\begin{array}{lll}
C_4 & 2.2969 \times 10^{-3} & C_6 & 4.7767 \times 10^{-4} & C_8 & -3.1569 \times 10^{-4} \\
C_{10} & -1.9939 \times 10^{-4} & C_{11} & -4.1969 \times 10^{-7} & C_{13} & -1.3660 \times 10^{-5} \\
C_{15} & -4.6817 \times 10^{-6} & & & &
\end{array}$$

F F S ⑤

$$\begin{array}{lll}
C_4 & 2.5793 \times 10^{-2} & C_6 & -4.2457 \times 10^{-3} & C_{11} & -4.8745 \times 10^{-4} \\
C_{13} & -1.7443 \times 10^{-4} & C_{15} & -3.6717 \times 10^{-5} & &
\end{array}$$

Displacement and tilt(1)

$$\begin{array}{llll}
X & 0.00 & Y & 10.19 & Z & 29.40 \\
\alpha & 7.35 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(2)

$$\begin{array}{llll}
X & 0.00 & Y & -3.29 & Z & 36.33 \\
\alpha & -25.35 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(3)

$$\begin{array}{llll}
X & 0.00 & Y & 24.99 & Z & 36.53 \\
\alpha & 82.49 & \beta & 0.00 & \gamma & 0.00
\end{array}$$

Displacement and tilt(4)

X 0.00 Y 18.12 Z 7.32
 α -18.71 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 18.12 Z -7.32
 α 18.71 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 24.00 Z 0.00
 α 90.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 0.00 Z 1.73
 α 0.00 β 0.00 γ 0.00

Example 3 0

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	A S S ①	(1)		1.5254	56.2
3	F F S ① (R E)	(2)		1.5254	56.2
4	A S S ① (R E)	(1)		1.5254	56.2
5	F F S ②	(3)			
6	F F S ③	(4)		1.5254	56.2
7	F F S ④ (R E)	(5)		1.5254	56.2
8	F F S ⑤	(6)			
Image plane	∞	(7)			

A S S ①

R	368.58
K	0.0000
A	7.6841×10^{-7}
B	-3.6756×10^{-11}

F F S ①

C_4	-2.7696×10^{-3}	C_6	-1.4546×10^{-3}	C_8	-5.7608×10^{-5}
C_{10}	-9.2334×10^{-5}	C_{11}	5.8163×10^{-7}	C_{13}	3.5074×10^{-6}
C_{15}	2.2152×10^{-6}	C_{17}	-1.8054×10^{-7}	C_{19}	-1.1334×10^{-7}
C_{21}	-1.0782×10^{-7}				

F F S ②

C_4	3.3609×10^{-4}	C_6	8.4179×10^{-2}	C_8	-3.1419×10^{-5}
C_{10}	3.1128×10^{-3}	C_{11}	3.4030×10^{-5}	C_{13}	-1.1634×10^{-4}
C_{15}	3.9570×10^{-5}				

F F S ③

C_4	-3.7622×10^{-3}	C_6	-3.6532×10^{-3}	C_8	1.5526×10^{-4}
C_{10}	-5.4887×10^{-6}	C_{11}	-7.4035×10^{-6}	C_{13}	1.0763×10^{-5}
C_{15}	-6.6288×10^{-7}				

F F S ④

C_4	3.7622×10^{-3}	C_6	3.6532×10^{-3}	C_8	-1.5526×10^{-4}
C_{10}	5.4887×10^{-6}	C_{11}	7.4035×10^{-6}	C_{13}	-1.0763×10^{-5}
C_{15}	6.6288×10^{-7}				

F F S ⑤

C_4	2.8169×10^{-2}	C_6	4.5388×10^{-4}	C_{11}	-4.5848×10^{-4}
C_{13}	-8.7689×10^{-5}	C_{15}	-8.8053×10^{-6}		

Displacement and tilt(1)

X	0.00	Y	17.47	Z	30.07
α	-1.32	β	0.00	γ	0.00

Displacement and tilt(2)

X 0.00 Y 0.39 Z 38.40
 α -28.76 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 30.09 Z 31.35
 α 36.81 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 19.88 Z 6.67
 α -15.86 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 19.88 Z -6.67
 α 15.86 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 29.00 Z 0.00
 α 90.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 0.00 Z 1.82
 α 0.00 β 0.00 γ 0.00

上記実施例 16、20、22、29、30 の横収差をそれぞれ図 34、図 35、図 36、図 37、図 38 に示す。これらの横収差図において、括弧内に示された数字は（水平画角，垂直画角）を表し、その画角における横収差を示す。

なお、上記実施例 16～28 の後記条件式（4）、（6）の値は次の通りである。

	条件式（4） θ_1 （°）	条件式（6） ΣD_1 （mm）
実施例16	22.5	119.4
実施例17	41.0	57.7
実施例18	37.2	62.5

実施例19	22.0	33.4
実施例20	26.1	99.4
実施例21	18.8	92.7
実施例22	25.6	95.7
実施例23	41.2	58.3
実施例24	36.6	50.1
実施例25	22.7	70.4
実施例26	20.4	78.5
実施例27	43.8	56.2
実施例28	31.2	117.5

次に、上記実施例 29、30 の前記条件式 (1) ~ (3) に関する値を下記に示す。

		実施例 29	実施例 30
条件式 (1)	α	$43^\circ \leq \alpha \leq 54^\circ$	$43^\circ \leq \alpha \leq 58^\circ$
条件式 (2)	β	19°	18°
条件式 (3)	D	27.5mm	31mm
	L	72mm	72mm
	D/L	0.38	0.43

なお、上記実施例 16 ~ 30 の各自由曲面は、平面を含む球面、非球面、アナモフィック面、アナモフィック非球面に置き換えることも可能である。

ところで、以上のような本発明の画像表示装置の光学系において、画像表示素子 3 の表示する像中心と右眼用接眼プリズム 2 R の形成する右側瞳 4 R 中心とを通る光線を右側光軸とし、画像表示素子 3 の表示する像中心と左眼用接眼プリズム 2 L の形成する左側瞳 4 L 中心とを通る光線を左側光軸としたときに、光路振分けミラー 1 又は光路振分けプリズム 10 から右眼用接眼プリズム 2 R 及び左眼用接眼プリズム 2 L に入射する右側光軸及び左側光軸と画像表示素子 3 の表示面

とのなす角度の絶対値を θ_1 とするとき、

$$10^\circ < \theta_1 < 60^\circ \quad \dots (4)$$

を満足するように構成されていることが望ましい。

上記条件式(4)は、光路振分けミラー1又は光路振分けプリズム10からなる光路振り分け手段から接眼プリズム2R、2Lに入射するときの軸上主光線と画像表示素子3とのなす角度を制限するものである。

上記条件式(4)の下限の 10° を越えると、光路振り分け手段から接眼プリズムに入射する軸上主光線が画像表示素子と略平行な光路をなってしまう、左右の光路を確保することが難しくなり、1つのLCD等の画像表示素子から左右の接眼プリズムに光路を振り分けるためにはハーフミラーを使用しなければならなくなり、画像が暗くなるため好ましくない。上記条件式(4)の上限の 60° を越えると、接眼プリズムを大きく傾けるか、あるいは、プリズム自体を大きくする必要があり、光学系の小型化・軽量化が達成できなくなる。

上記条件式はさらに以下の条件式(5)であることが望ましい。

$$15^\circ < \theta_1 < 50^\circ \quad \dots (5)$$

上記条件式の範囲内であれば、左右の光路を確保しながら装置の更なる小型化が達成できる。

また、画像表示素子3から右眼用接眼プリズム2R及び左眼用接眼プリズム2Lの入射面21R、21Lまでの光軸上の距離を ΣD_1 とすると、

$$20\text{ mm} < \Sigma D_1 < 150\text{ mm} \quad \dots (6)$$

を満足するように構成されていることが望ましい。

上記条件式(6)は、装置の小型化を達成するための条件式であり、画像表示素子3から接眼プリズム2R、2Lまでの軸上主光線の光路長を規定したものである。

上記条件式(6)の下限の 20 mm を越えると、光路振り分け手段の各面のパワーが非常に強くなり、偏心収差、特に偏心コマ収差が良好に補正できなくなる。また、画像表示素子3と光線との角度(主光線傾角)が非常に大きくなり、好ましくない。また、上記条件式(6)の上限の 150 mm を越えるを、光路振り

分け手段が大きくなり、接眼プリズムと比較して大きく突出した形状になってしまいうため好ましくない。

上記条件式はさらに以下の条件式（７）であることが望ましい。

$$30\text{ mm} < \Sigma D_1 < 130\text{ mm} \quad \dots (7)$$

上記条件式の範囲内であれば、性能を良好に保ちながら装置の更なる小型化が達成できる。

上記条件式はさらに以下の条件式（８）であることが望ましい。

$$45\text{ mm} < \Sigma D_1 < 120\text{ mm} \quad \dots (8)$$

上記条件式の範囲内であれば、性能を良好に保ちながら装置の更なる小型化が達成できる。

さて、本発明の画像表示装置の以上のような光学系において、図３９に例示するように、左右眼用の偏心プリズム体２Ｌ、２Ｒの外界側（観察者顔面側と反対側）の反射面２３Ｌ、２３Ｒ（図２６の場合は、反射面２２Ｌ、２２Ｒ。図２７の場合は、２２Ｌ、２２Ｒ、２４Ｒ、２４Ｒ。図２８の場合は、２３Ｌ、２３Ｒ。）をハーフミラー面として、その外界側に光路の曲がりを補償する補償プリズム１６Ｌ、１６Ｒを貼り付けるか若干離間して配置し、その補償プリズム１６Ｌ、１６Ｒの外界側の面１７Ｌ、１７Ｒを左右眼用の偏心プリズム体２Ｌ、２Ｒの観察者顔面側の透過面２４Ｌ、２４Ｒ（図２６の場合は、透過面２３Ｌ、２３Ｒ。図２７の場合は、２５Ｌ、２５Ｒ。図２８の場合は、２４Ｌ、２４Ｒ。）と略同じ形状の面とすることにより、外界からの光が略直通して外界のシースルー観察が可能になる。この場合は、補償プリズム１６Ｌ、１６Ｒの外界側に液晶シャッター等の外界光の透過率を切り換える手段を配置すれば、スーパーインポーズ機能やシースルー機能が付加できる。

また、本発明において、画像表示素子３として、前記したように、透過型あるいは反射型のＬＣＤ（液晶表示素子）を用いることができるが、自己発光型パネルを使うことにより構造を簡単にして、軽量の画像表示装置を構成することができる。画像表示素子３にＬＣＤを用いると、バックライト等の照明光源が必要となる問題点と、ＬＣＤの場合は偏光板を必ず必要として、照明光の半分しか表示

に使うことができない問題点がある。

そこで、自己発光型パネル（ディスプレイ）を用いることが望ましい。自己発光型パネルには、OLED（Organic Light Emitting Diodes）やLED（Light Emitting Diodes）、図40にその構造を例示したようなEL（Electroluminescence）パネル等がある。

図40は、3層構成の有機ELの構造を示すもので、Si基板上に設けられ各画素毎にスイッチング素子が配置された画素電極と、ガラス基板の下面に設けられた共通電極のITO膜との間に、正孔注入層と有機EL層と電子注入層との3層からなる有機EL層が挟持され、スイッチング素子の作用で画素電極とITO膜との間に電圧が印加されると、正孔注入層からは正孔が、電子注入層からは電子が有機EL層中に注入され、有機EL層中で再結合することにより、その画素の有機EL層が発光することになり、所要の画像が表示される。

このような発光型ディスプレイを画像表示装置に使うメリットは、その視野角特性の良さにある。特に、両眼視する頭部装着式画像表示装置（HMD）においては、観察者の眼幅の違いやHMD本体のずれ等により、光学系の瞳と観察者の瞳がずれることがある。観察者の瞳がずれても観察像が陰らないようにするには、光学系の瞳を広い範囲で収差がないようにするのが重要である。光学系の設計において、瞳を広く設計しても、瞳がずれた場合は、接眼光学系を通して見ると、画像表示素子を斜めから観察している状態となる。一般に、LCDの画像表示素子はこの斜めから見る視野角特性が良くなく、コントラストが低下したり白黒が反転した観察像しか観察することができなくなってしまう。そのため、HMDの装着位置により画面の明るさやコントラストが変化してしまい、安定した画質で観察することが難しい。発光型画像表示素子では、このような問題が発生し難く、このため、HMD用画像表示素子として好ましいものである。

さて、以上に説明したような本発明の画像表示装置を1組用意して支持することにより、据え付け型又はポータブル型の画像表示装置として構成することができる。その様子を図41に示す。図41中、31は表示装置本体部を示し、観察

者の顔面の両眼の前方に保持されるよう支持部材が頭部を介して固定している。その支持部材としては、一端を表示装置本体部 3 1 に接合し、観察者のこめかみから耳の上部にかけて延在する左右の前フレーム 3 2 と、前フレーム 3 2 の他端に接合され、観察者の側頭部を渡るように延在する左右の後フレーム 3 3 とから、あるいは、さらに、左右の後フレーム 3 3 の他端に挟まれるように自らの両端を一方ずつ接合し、観察者の頭頂部を支持する頭頂フレーム 3 4 とから構成されている。

また、前フレーム 3 2 における上記の後フレーム 3 3 との接合近傍には、弾性体からなり例えば金属板バネ等で構成されたリヤプレート 3 5 が接合されている。このリヤプレート 3 5 は、上記支持部材の一翼を担うリヤカバー 3 6 が観察者の後頭部から首のつけねにかかる部分で耳の後方に位置して支持可能となるように接合されている。リヤプレート 3 5 又はリヤカバー 3 6 内に観察者の耳に対応する位置にスピーカー 3 9 が取り付けられている。

映像・音声信号等を外部から送信するためのケーブル 4 1 が表示装置本体部 3 1 から、頭頂フレーム 3 4、後フレーム 3 3、前フレーム 3 2、リヤプレート 3 5 の内部を介してリヤプレート 3 5 あるいはリヤカバー 3 6 の後端部より外部に突出している。そして、このケーブル 4 1 はビデオ再生装置 4 0 に接続されている。なお、図中、4 0 a はビデオ再生装置 4 0 のスイッチやボリューム調整部である。

なお、ケーブル 4 1 は先端をジャックして、既存のビデオデッキ等に取り付け可能としてもよい。さらに、TV 電波受信用チューナーに接続してTV鑑賞用としてもよいし、コンピュータに接続してコンピュータグラフィックスの映像や、コンピュータからのメッセージ映像等を受信するようにしてもよい。また、邪魔なコードを排斥するために、アンテナを接続して外部からの信号を電波によって受信するようにしても構わない。

産業上の利用可能性

以上の説明から明らかなように、本発明によると、1つの画像表示素子からの

画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の中央に配置する光路振分けミラーあるいは光路振分けプリズムを持たせることで、諸収差の補正を容易にして、頭部装着式画像表示装置等の画像表示装置を提供することができる。また、このような構成において、表示画像を左右で切り換えずに使用できる単板両眼視に最適な照明配置を得ることができる。

請 求 の 範 囲

〔１〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けミラーと、前記光路振分けミラーの右側に配置された右眼用接眼プリズムと、前記光路振分けミラーの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けミラーが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束を、前記右眼用接眼プリズムと前記左眼用プリズムとに振分けて反射するミラー面を有し、前記ミラー面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記右眼用接眼プリズムが、前記光路振分けミラーで反射された右眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で右眼用光路の光束を反射する第２面と、プリズム外に右眼用光路の光束を射出する第３面とを有し、

前記左眼用接眼プリズムが、前記光路振分けミラーで反射された左眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で左眼用光路の光束を反射する第２面と、プリズム外に左眼用光路の光束を射出する第３面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第２面と、前記左眼用接眼プリズムの反射作用面である第２面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする画像表示装置。

〔２〕 前記光路振分けミラーの有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項１記載の画像表示装置。

〔３〕 前記光路振分けミラーの有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心と前記左眼用接眼プリズムの形成する左側瞳中心とを結んだ面（Ｙ－Ｚ平面）を前記唯一の対称面として構成されていることを特徴とする請求項２記載の画像表示装置。

〔４〕 前記画像表示素子が、前後方向（Ｚ方向）で前記光路振分けミラー

と観察者との間に配置され、かつ、左右方向（Y方向）で前記右眼用接眼プリズムと前記左眼用接眼プリズムとの間に配置されて構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔5〕 前記画像表示素子と前記光路振分けミラーの間に、光束に負のパワーを与える負レンズを配置して構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔6〕 前記右眼用接眼プリズムが、前記光路振分けミラーから射出され前記第1面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けミラーから射出され前記第1面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔7〕 前記右眼用接眼プリズムの前記第1面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの前記第1面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔8〕 前記右眼用接眼プリズムの前記第1面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成され、

前記左眼用接眼プリズムの前記第1面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項7記載の

画像表示装置。

〔 9 〕 前記右眼用接眼プリズムの前記第 1 面が有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Y-Z 面）を前記唯一の対称面として構成され、

前記左眼用接眼プリズムの前記第 1 面が有する自由曲面が、前記画像表示素子の表示する像中心と前記左眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Y-Z 面）を前記唯一の対称面として構成されていることを特徴とする請求項 8 記載の画像表示装置。

〔 1 0 〕 前記右眼用接眼プリズムの前記第 3 面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの前記第 3 面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項 1 ～ 3 の何れか 1 項記載の画像表示装置。

〔 1 1 〕 前記右眼用接眼プリズムの前記第 3 面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成され、

前記左眼用接眼プリズムの前記第 3 面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項 1 0 記載の画像表示装置。

〔 1 2 〕 前記右眼用接眼プリズムの前記第 3 面が有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Y-Z 面）を前記唯一の対称面として構成され、

前記左眼用接眼プリズムの前記第 3 面が有する自由曲面が、前記画像表示素子の表示する像中心と前記左眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Y-Z 面）を前記唯一の対称面として構成されていることを特徴とする請求項 1 1 記載

の画像表示装置。

〔13〕 前記右眼用接眼プリズムの前記第3面が、回転対称非球面にて構成され、

前記左眼用接眼プリズムの前記第3面が、回転対称非球面にて構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔14〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第1面と、前記第1面から入射した前記右眼用光路を反射する第21面と、前記第1面から入射した前記左眼用光路を反射する第22面と、前記右眼用光路の光束をプリズム外に射出させる第31面と、前記左眼用光路の光束をプリズム外に射出させる第32面と、を少なくとも有し、

前記光路振分けプリズムは、前記右眼用光路中に前記画像表示素子の表示した像から右眼用リレー像を形成し、かつ、前記左眼用光路中に前記画像表示素子の表示した像から左眼用リレー像を形成するために、少なくとも前記第21面と前記第22面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第21面と前記第22面とが同一の面形状を有するように構成され、

前記右眼用接眼プリズムが、前記光路振分けプリズムの前記第31面から射出された右眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で右眼用光路の光束を反射する第2面と、プリズム外に右眼用光路の光束を射出する第3面とを有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムの前記第32面から射出された左眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で左眼用光路の光束を反射する第2面と、プリズム外に左眼用光路の光束を射出する第3面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第2面と、前記左眼用接眼プリズムの反射作用面である第2面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする画像表示装置。

〔15〕 前記光路振分けプリズムの第31面と第32面とが、同一形状の曲面にて構成されていることを特徴とする請求項14記載の画像表示装置。

〔16〕 前記光路振分けプリズムの第1面と第21面と第22面と第31面と第32面とが、それぞれ独立した面としてプリズムの有する光学面を形成し、

前記光路振分けプリズムの第21面と第22面と第31面と第32面との曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項14又は15記載の画像表示装置。

〔17〕 前記光路振分けプリズムの第31面と第32面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項15記載の画像表示装置。

〔18〕 前記光路振分けプリズムの第21面と第22面と第31面と第32面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項15記載の画像表示装置。

〔19〕 前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Z方向）に離れるに従って、前記第1面が配置され、媒質を挟んだ左右の位置に前記第21面と前記第22面とが配置され、さらに、前記第31面と前記第32面とが配置されるように構成され、

前記右眼用接眼プリズムの第1面と空気間隔を挟んで対向する位置に前記第31面が配置され、かつ、前記左眼用接眼プリズムの第1面と空気間隔を挟んで対向する位置に前記第32面が配置されるように構成されていることを特徴とする請求項15～18の何れか1項記載の画像表示装置。

〔20〕 前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Z方向）に離れるに従って、前記第1面が配置され、媒質を挟んだ左右の位置に前記第3 1面と前記第3 2面とが配置され、さらに、前記第2 1面と前記第2 2面とが配置されるように構成され、

前記右眼用接眼プリズムの第1面と空気間隔を挟んで対向する位置に前記第3 1面が配置され、かつ、前記左眼用接眼プリズムの第1面と空気間隔を挟んで対向する位置に前記第3 2面が配置されるように構成されていることを特徴とする請求項1 5～1 8の何れか1項記載の画像表示装置。

〔2 1〕 前記光路振分けプリズムは、前記第2 1面と前記第3 2面とが1つの面にて兼用されて構成されると共に、前記第2 2面と前記第3 1面とが1つの面にて兼用されて構成され、

前記右眼用光路を全反射臨界角よりも大きい角度で前記第2 1面と前記第3 2面との兼用面に入射させることによって全反射作用によりプリズム内で右眼用光路の光束を反射させ、前記右眼用光路を全反射臨界角よりも小さい角度で前記第2 2面と前記第3 1面との兼用面に入射させることによって右眼用光路の光束をプリズム外に射出させ、

前記左眼用光路を全反射臨界角よりも大きい角度で第2 2面と第3 1面との兼用面に入射させることによって全反射作用によりプリズム内で左眼用光路の光束を反射させ、前記左眼用光路を全反射臨界角よりも小さい角度で第2 1面と第3 2面との兼用面に入射させることによって左眼用光路の光束をプリズム外に射出させ、

前記第2 1面と第3 2面との兼用面の曲面形状が偏心収差を補正するような回転非対称な曲面形状にて構成され、かつ、前記第2 2面と第3 1面との兼用面の曲面形状が偏心収差を補正するような回転非対称な曲面形状にて構成されていることを特徴とする請求項1 4記載の画像表示装置。

〔2 2〕 前記光路振分けプリズムが、第1面から入射した左右の像の光束を第2 1面と第2 2面とに向けて反射する曲面形状の第4面を有し、

前記光路振分けプリズムの第 1 面と第 2 1 面と第 2 2 面と第 3 1 面と第 3 2 面と第 4 面とが、それぞれ独立した面としてプリズムの有する光学面を形成していることを特徴とする請求項 1 4 ～ 1 8 の何れか 1 項記載の画像表示装置。

〔 2 3 〕 前記光路振分けプリズムの第 4 面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項 2 2 記載の画像表示装置。

〔 2 4 〕 前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Z 方向）に離れるに従って、前記第 1 面が配置され、媒質を挟んだ左右の位置に前記第 2 1 面と前記第 2 2 面とが配置され、媒質を挟んだ左右の位置に前記第 3 1 面と前記第 3 2 面とが配置され、

さらに、前記第 1 面と媒質を挟んで対向する位置に前記第 4 面が配置されるように構成され、

前記右眼用接眼プリズムの第 1 面と空気間隔を挟んで対向する位置に前記第 3 1 面が配置され、かつ、前記左眼用接眼プリズムの第 1 面と空気間隔を挟んで対向する位置に前記第 3 2 面が配置されるように構成されていることを特徴とする請求項 2 3 記載の画像表示装置。

〔 2 5 〕 前記光路振分けプリズムが、第 1 面から入射した右眼用光路を第 2 1 面に向けて反射する第 4 1 面と、第 1 面から入射した左眼用光路を第 2 2 面に向けて反射する第 4 2 面とを有し、

前記光路振分けプリズムの第 1 面と第 2 1 面と第 2 2 面と第 3 1 面と第 3 2 面と第 4 1 面と第 4 2 面とが、それぞれ独立した面としてプリズムの有する光学面を形成していることを特徴とする請求項 1 4 ～ 1 8 の何れか 1 項記載の画像表示装置。

〔 2 6 〕 前記光路振分けプリズムの第 4 1 面と第 4 2 面とが、同一形状の曲面にて構成されていることを特徴とする請求項 2 5 記載の画像表示装置。

〔 2 7 〕 前記光路振分けプリズムの第 4 1 面と第 4 2 面の曲面形状が、偏

心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項 2 6 記載の画像表示装置。

〔28〕 前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Z 方向）に離れるに従って、前記第 1 面が配置され、媒質を挟んだ左位置に第 2 1 面が、媒質を挟んだ右位置に第 2 2 面が配置され、媒質を挟んだ左位置に第 3 2 面が、媒質を挟んだ右位置に第 3 1 面が配置され、前記第 1 面と媒質を挟んで対向する位置に第 4 1 面と第 4 2 面とが隣接して配置されるように構成されていることを特徴とする請求項 2 7 記載の画像表示装置。

〔29〕 前記光路振分けプリズムの前記第 1 面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項 1 4 ～ 2 8 の何れか 1 項記載の載の画像表示装置。

〔30〕 前記光路振分けプリズムの有する回転非対称な曲面が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項 1 4 ～ 1 8 の何れか 1 項記載の画像表示装置。

〔31〕 前記光路振分けプリズムの有する自由曲面が、前記画像表示素子の表示する像中心と瞳中心とを結んだ面（Y-Z 平面）を前記唯一の対称面として構成されていることを特徴とする請求項 3 0 記載の画像表示装置。

〔32〕 前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第 3 面に入射させることによって全反射作用によりプリズム内で前記第 2 面に向けて反射させ、前記第 2 面で反射した光束を全反射臨界角よりも小さい角度で前記第 3 面に入射させることによってこの第 3 面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第 3 面に入射させることによって全反射作用によりプリズム内で前記第 2 面に向け

て反射させ、前記第 2 面で反射した光束を全反射臨界角よりも小さい角度で前記第 3 面に入射させることによってこの第 3 面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

〔33〕 前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を前記第 2 面で反射させ、前記第 2 面で反射した光束を前記第 3 面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を前記第 2 面で反射させ、前記第 2 面で反射した光束を前記第 3 面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

〔34〕 前記右眼用接眼プリズムが、光束をプリズム内で反射する第 4 面を有し、

前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を前記第 4 面で反射し、前記第 4 面から反射された光束を全反射臨界角よりも大きい角度で前記第 3 面に入射させることによって全反射作用によりプリズム内で前記第 2 面に向けて反射させ、前記第 2 面で反射した光束を全反射臨界角よりも小さい角度で前記第 3 面に入射させることによってこの第 3 面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、光束をプリズム内で反射する第 4 面を有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第 1 面を透過してプリズム内に入射した光束を前記第 4 面で反射し、前記第 4 面から反射された光束を全反射臨界角よりも大きい角度で前記第 3 面に入射させることによって全反射作用によりプリズム内で前記第 2 面に向けて反射させ、前記第 2 面で反射した光束を全反射臨界角よりも小さい角度で前記第 3 面に入射させること

によってこの第3面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項14～18の何れか1項記載の画像表示装置。

〔35〕 前記右眼用接眼プリズムの第4面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第4面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項34記載の画像表示装置。

〔36〕 前記右眼用接眼プリズムの第1面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第1面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項14～18の何れか1項記載の画像表示装置。

〔37〕 前記右眼用接眼プリズムの第2面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第2面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項14～18の何れか1項記載の画像表示装置。

〔38〕 前記右眼用接眼プリズムの第3面が、回転対称非球面にて構成され、

前記左眼用接眼プリズムの前記第3面が、回転対称非球面にて構成されていることを特徴とする請求項14～18の何れか1項記載の画像表示装置。

〔39〕 前記右眼用接眼プリズムの第3面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第3面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項14～18の何れか1項記載の画像表示装置。

〔40〕 前記光路振分けプリズムは、前記右眼用リレー像を前記第31面よりも光路上観察者の右眼側の位置に形成すると共に、前記左眼用リレー像を前記第32面よりも光路上観察者の左眼側の位置に形成するように、全体として正

のパワーを有するように構成されていることを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

〔41〕 前記光路振分けプリズムは、前記右眼用リレー像を前記第 3 1 面と前記右眼用接眼プリズムの第 1 面との間の位置に形成すると共に、前記左眼用リレー像を前記第 3 2 面と前記左眼用接眼プリズムの第 1 面との間の位置に形成するように構成されていることを特徴とする請求項 40 記載の画像表示装置。

〔42〕 前記光路振分けプリズムの第 2 1 面からの右眼用光路の表示光の反射角 α 、及び、前記光路振分けプリズムの第 2 2 面からの左眼用光路の表示光の反射角 α が次の条件を満たすことを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

$$33^{\circ} \leq \alpha \leq 70^{\circ} \quad \dots (1)$$

〔43〕 右眼用射出瞳と左眼用射出瞳の中心間を結んだ線分の中心を通りその線分に垂直な平面と、前記光路振分けプリズムの第 2 1 面に右眼用光路の光軸が入射する点における前記第 2 1 面の接平面とがなす角 β 、及び、右眼用射出瞳と左眼用射出瞳の中心間を結んだ線分の中心を通りその線分に垂直な平面と、前記光路振分けプリズムの第 2 2 面に左眼用光路の光軸が入射する点における前記第 2 2 面の接平面とがなす角 β が次の条件を満たすことを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

$$13^{\circ} \leq \beta \leq 24^{\circ} \quad \dots (2)$$

〔44〕 瞳側から逆光線追跡した場合に、右眼用射出瞳中心を通る右側最大画角の光線と前記右眼用接眼プリズムの第 3 面とが交わる点と、左眼用射出瞳中心を通る左側最大画角の光線と前記左眼用接眼プリズムの第 3 面とが交わる点との間隔を横幅 L とし、また、左右の射出瞳中心を通る全画角内の光線束の中、前記右眼用接眼プリズムあるいは前記左眼用接眼プリズムの第 3 面を透過あるいは反射する点の中で最も左右の射出瞳側に近い点と、前記画像表示素子の表示面とのその表示面に垂直な方向の距離を奥行 D とし、横幅 L と奥行 D との比 D/L が次の条件を満たすことを特徴とする請求項 14～18 の何れか 1 項記載の画像表示装置。

$$0.3 \leq D/L \leq 0.5 \quad \dots (3)$$

〔４５〕 前記右眼用接眼プリズムの第２面が半透過反射面にて構成され、その第２面の外側に右眼用シースループリズムを配置し、

前記左眼用接眼プリズムの第２面が半透過反射面にて構成され、その第２面の外側に左眼用シースループリズムを配置したことを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔４６〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第１面と、前記第１面から入射した前記右眼用光路を反射する第２１面と、前記第１面から入射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、少なくとも、前記第２１面と、前記第２２面と、前記第３１面と、前記第３２面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有し、前記第３１面と前記第３２面とが同一の面形状を有するように構成され、

前記画像表示素子が、光源からの光束を反射することによって画像を表示する反射型画像表示素子から構成され、

前記光路振分けプリズムの有する、前記第２１面と前記第２２面とが共に、半透過反射面若しくは部分透過部分反射面の何れかにて構成され、

前記第２１面のプリズム媒質とは反対側の位置に左眼用の光路を形成するための左眼用照明光源を配置し、前記第２２面のプリズム媒質とは反対側の位置に右眼用の光路を形成するための右眼用照明光源を配置して構成されていることを特徴とする画像表示装置。

〔４７〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第１面と、前記第１面と媒質を挟んで対向配置され前記第１面から入射した左右の像の光束を異なった方向に反射させ右眼用光路と左眼用光路とに振り分ける第４面と、前記第４面から反射された前記右眼用光路を反射する第２１面と、前記第４面から反射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、少なくとも、前記第２１面と、前記第２２面と、前記第３１面と、前記第３２面と、前記第４面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有し、前記第３１面と前記第３２面とが同一の面形状を有するように構成され、

前記画像表示素子が、光源からの光束を反射することによって画像を表示する反射型画像表示素子から構成され、

前記光路振分けプリズムの有する前記第４面が、半透過反射面若しくは部分透過部分反射面の何れかにて構成され、

前記第４面のプリズム媒質とは反対側の位置に、左眼用の光路を形成するための左眼用照明光源と、右眼用の光路を形成するための右眼用照明光源とを配置して構成されていることを特徴とする画像表示装置。

〔４８〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素

子から射出された表示光束をプリズム内部に入射させる第1面と、前記右眼用光路を全反射臨界角よりも大きい角度で光学面に入射させることによって全反射作用によりプリズム内で右眼用光路の光束を反射させかつ前記左眼用光路を全反射臨界角よりも小さい角度で光学面に入射させることによって左眼用光路の光束をプリズム外に射出させる第2面と、前記左眼用光路を全反射臨界角よりも大きい角度で光学面に入射させることによって全反射作用によりプリズム内で左眼用光路の光束を反射させかつ前記右眼用光路を全反射臨界角よりも小さい角度で光学面に入射させることによって右眼用光路の光束をプリズム外に射出させる第3面と、を有し、

前記画像表示素子と前記第1面との間に表示用光学素子を配置し、

前記光路振分けプリズムは、前記第2面と前記第3面とが光束にパワーを与える同一形状の曲面にて構成され、かつ、前記第2面と前記第3面とをプリズム媒質を挟んで対向するように配置し、

前記画像表示素子が、光源からの光束を透過することによって画像を表示する透過型画像表示素子から構成され、

前記画像表示素子の前記表示用光学素子とは反対側の位置に、左眼用の光路を形成するための左眼用照明光源と、右眼用の光路を形成するための右眼用照明光源とを配置して構成されていることを特徴とする画像表示装置。

〔49〕 前記表示用光学素子が、フレネルレンズから構成されていることを特徴とする請求項48記載の画像表示装置。

〔50〕 前記光路振分けプリズムの第21面と前記第22面とが共に、透過と反射を強度的に分割するハーフミラーコーティングにて構成されていることを特徴とする請求項46記載の画像表示装置。

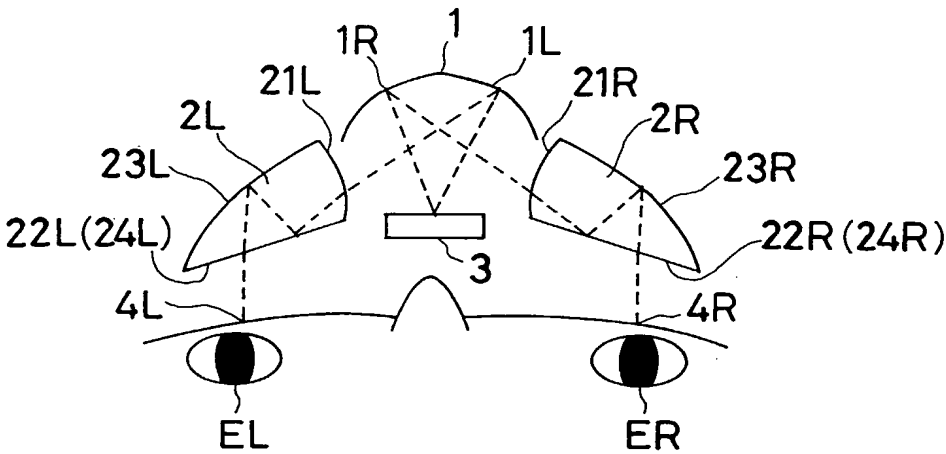
〔51〕 前記光路振分けプリズムの第21面と前記第22面とが共に、反射ミラー面内に透過孔を設けたミラーコーティングにて構成されていることを特徴とする請求項46記載の画像表示装置。

〔52〕 前記光路振分けプリズムの第4面が、透過と反射を強度的に分割するハーフミラーコーティングにて構成されたことを特徴とする請求項4

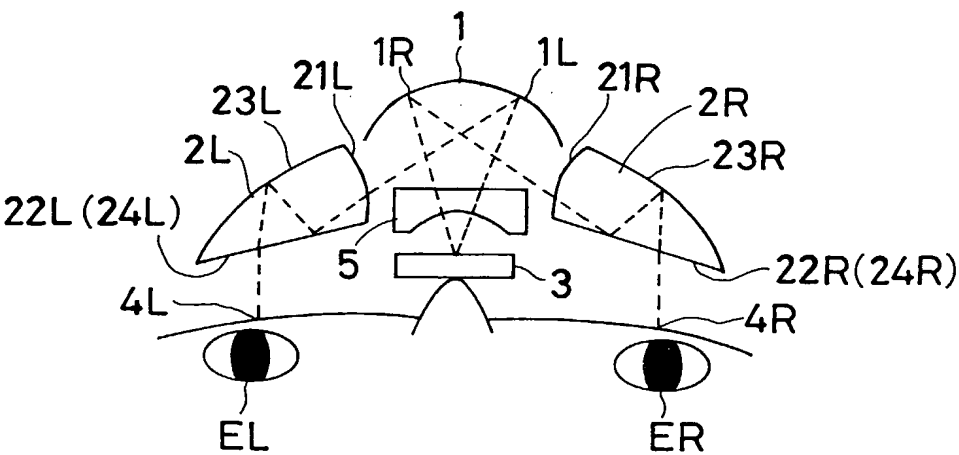
7 記載の画像表示装置。

〔53〕 前記光路振分けプリズムの第4面が、反射ミラー面内に透過孔を設けたミラーコーティングにて構成されていることを特徴とする請求項47記載の画像表示装置。

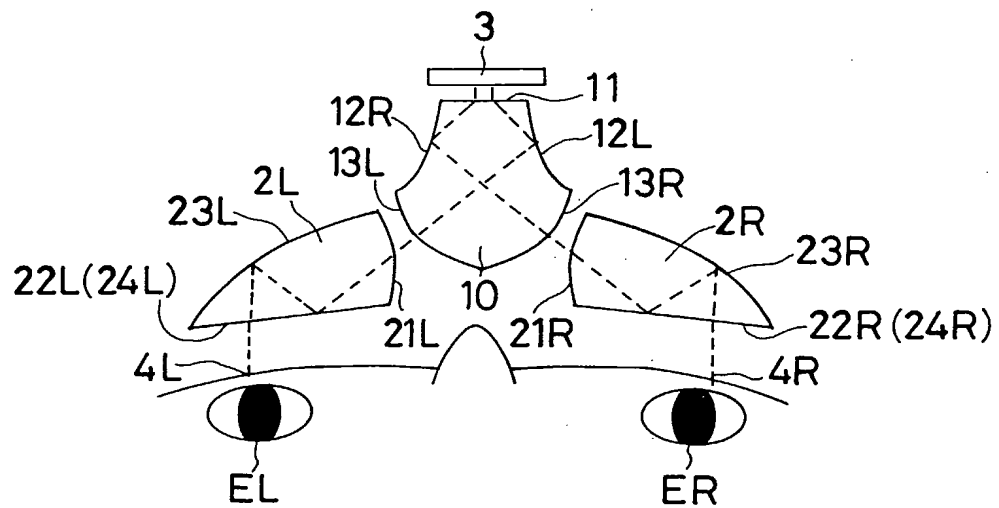
第 1 図



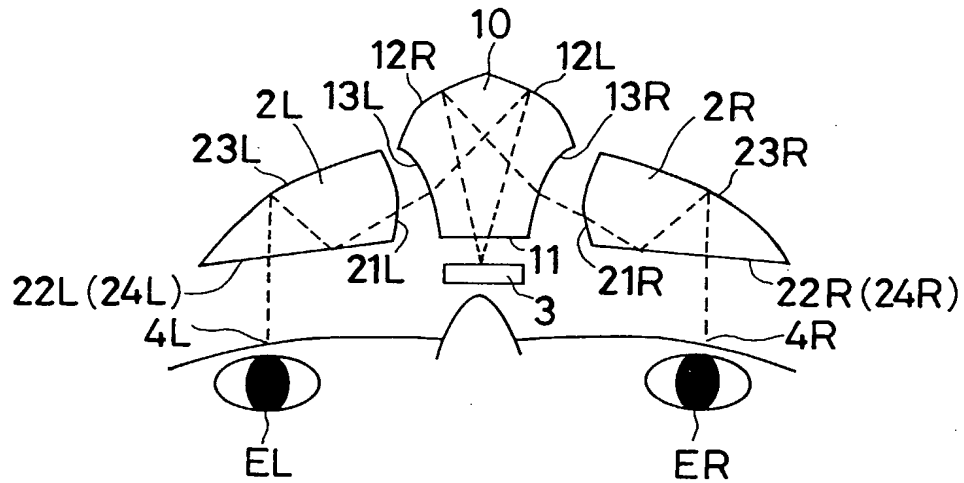
第 2 図



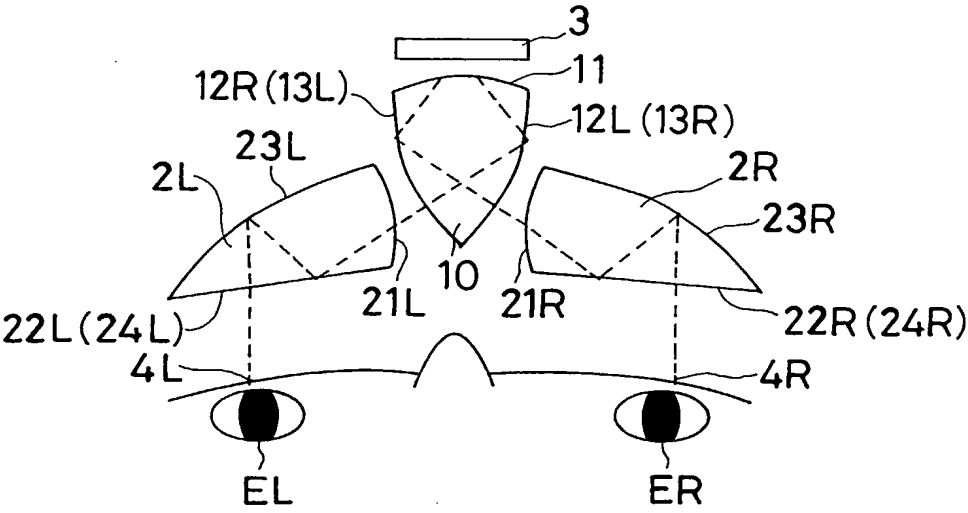
第 3 図



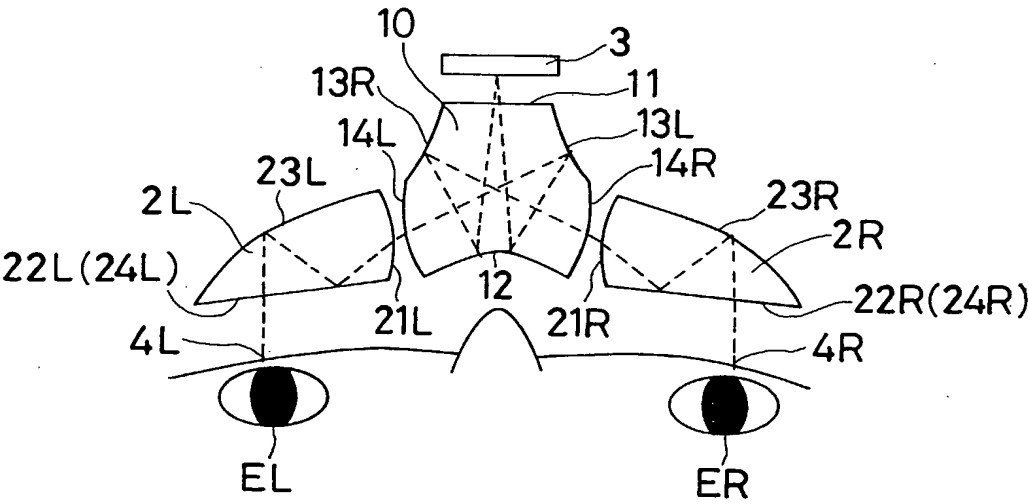
第 4 図



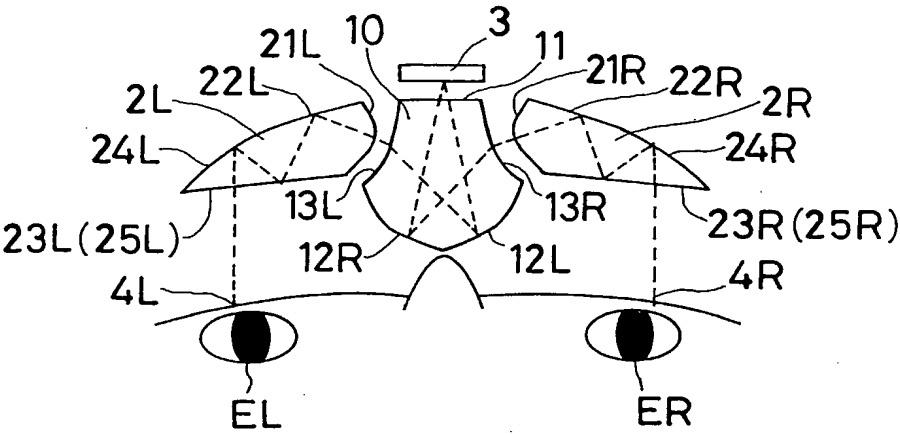
第 5 図



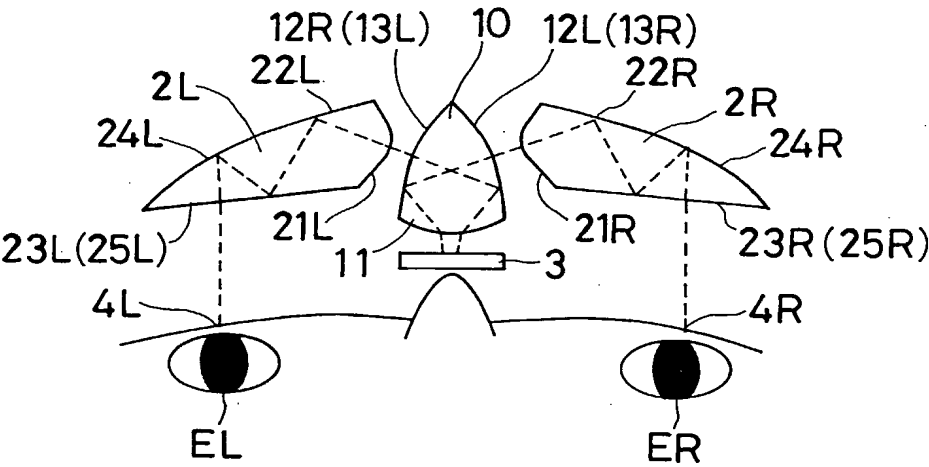
第 6 図



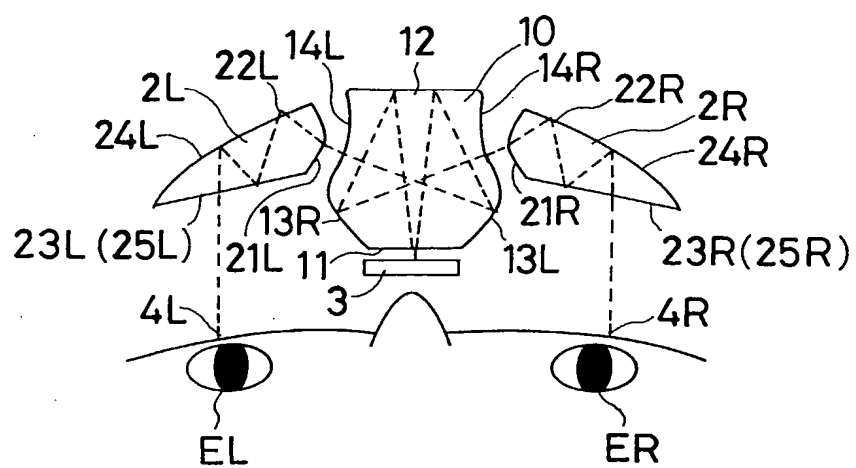
第 7 図



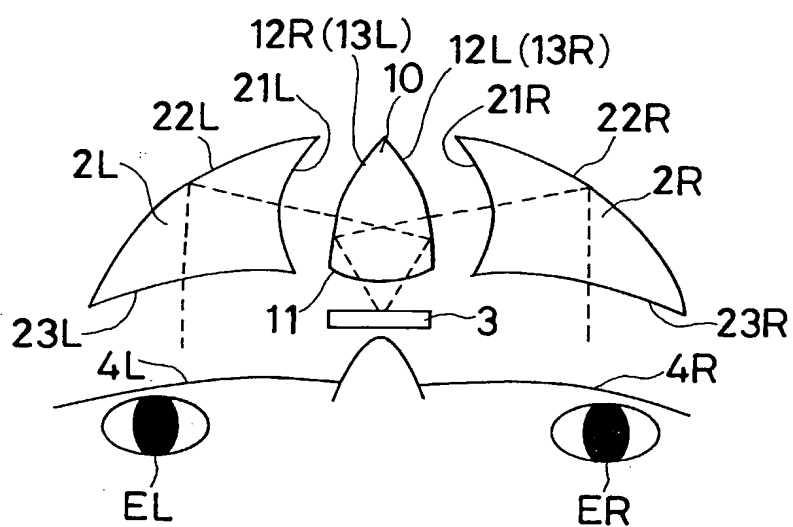
第 8 図



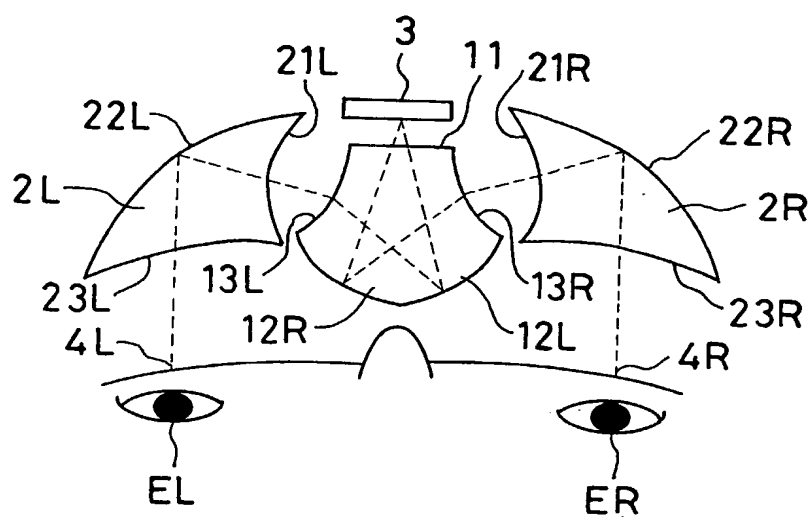
第 9 図



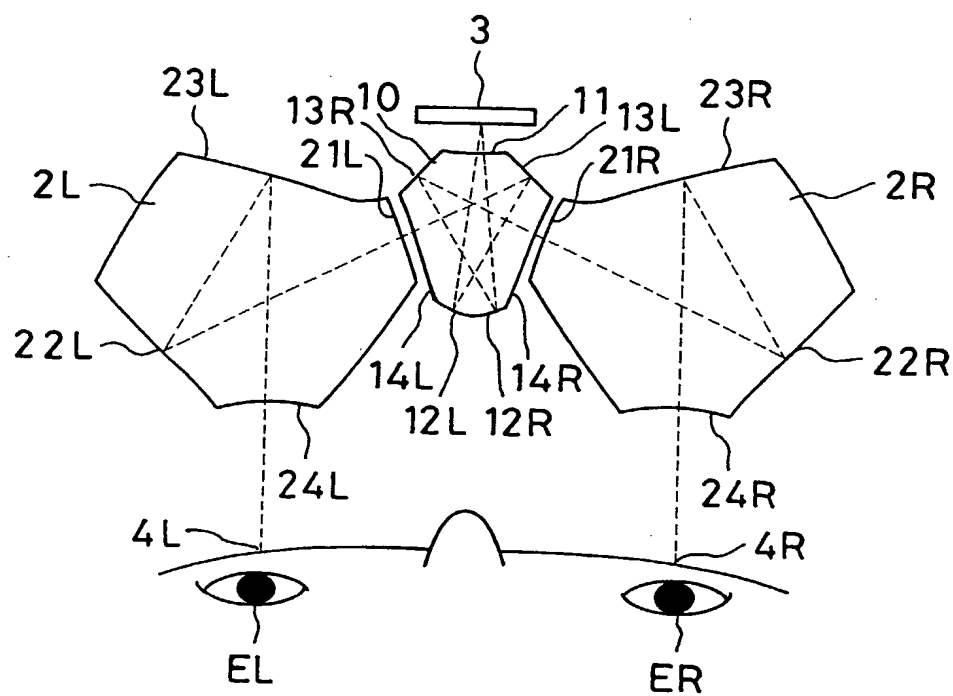
第 10 図



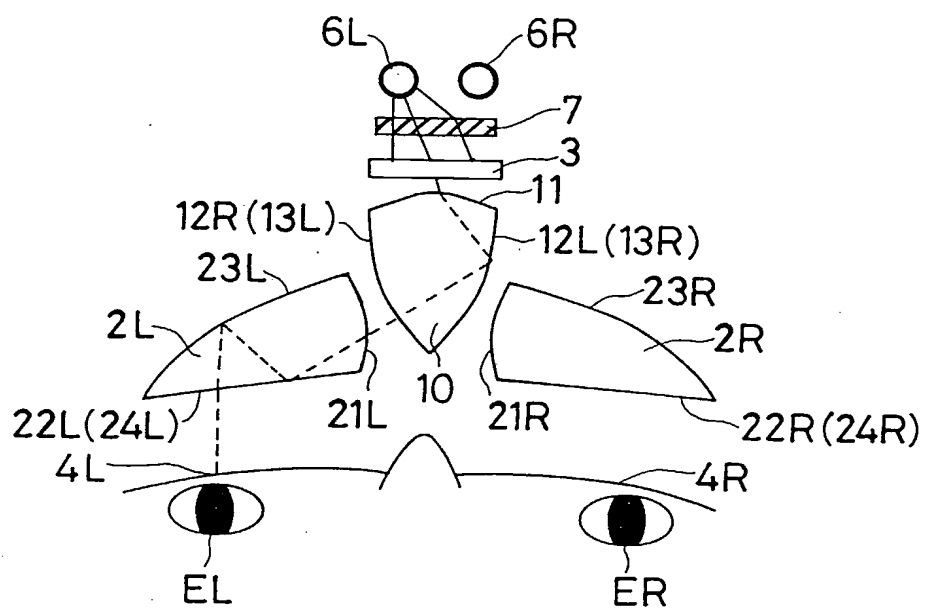
第 1 1 図



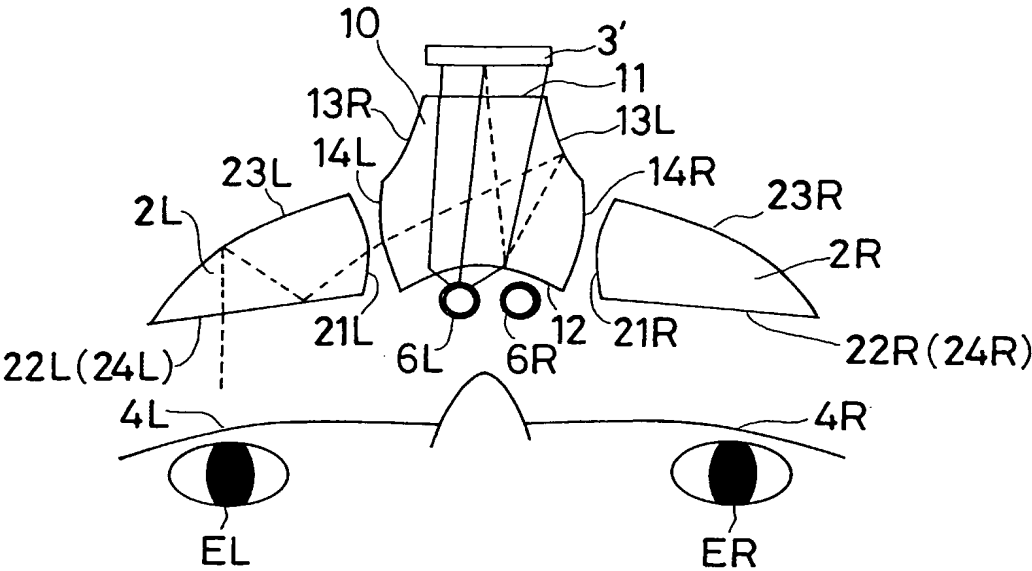
第 1 2 図



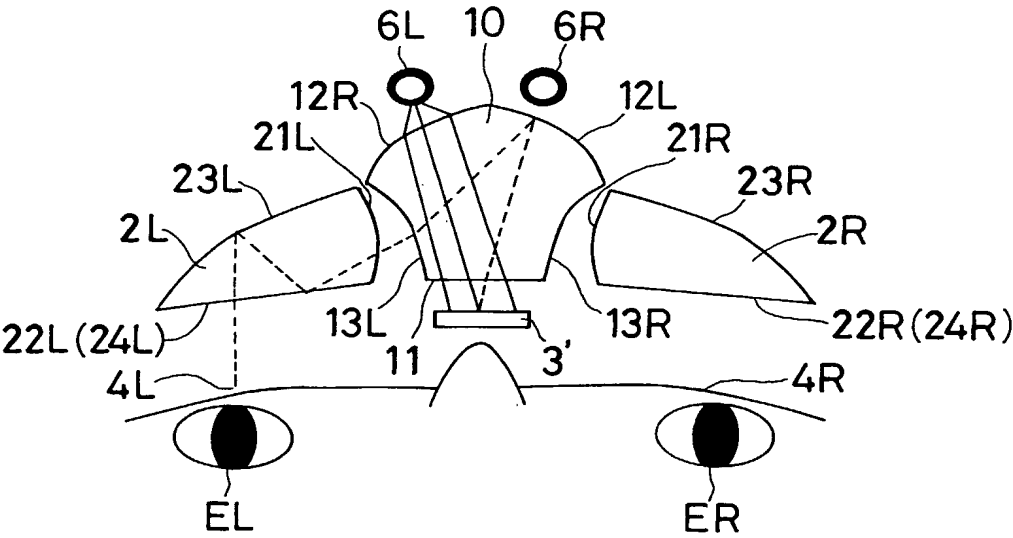
第 1 3 図



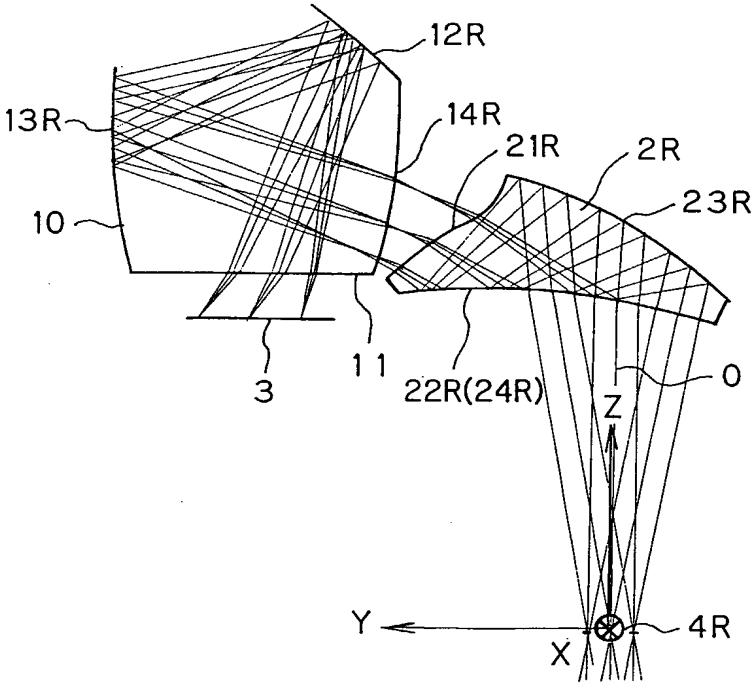
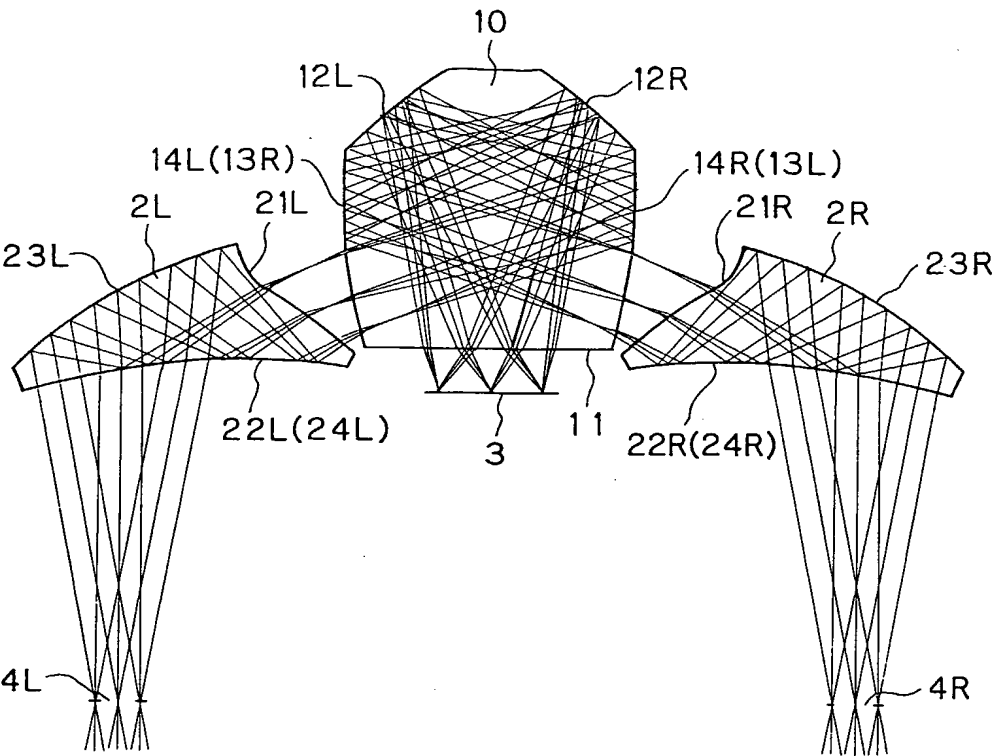
第 1 4 図



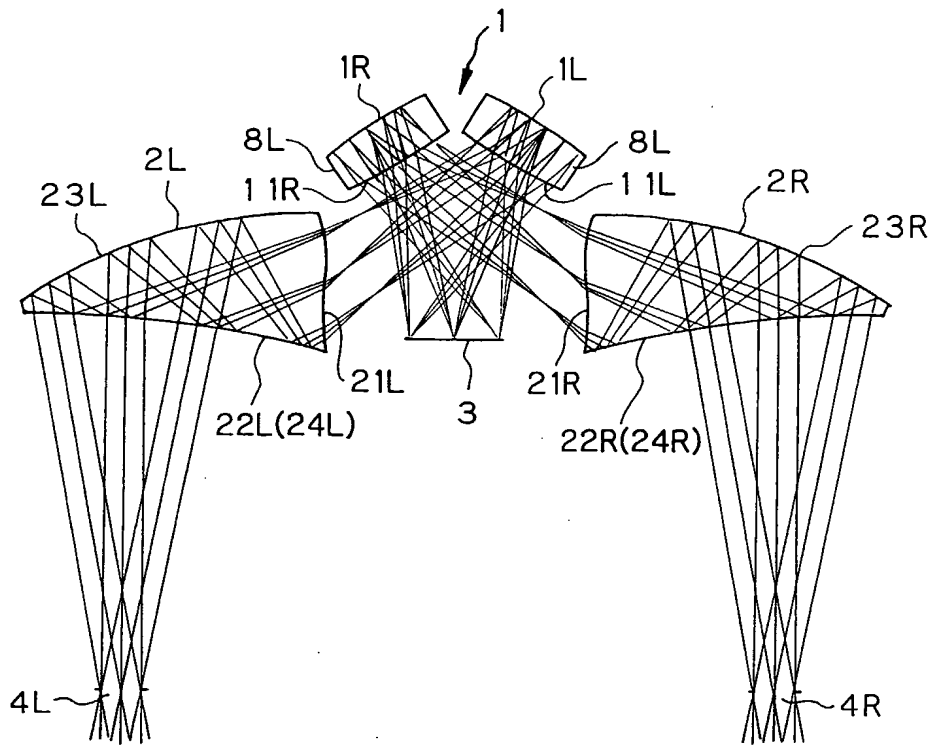
第 1 5 図



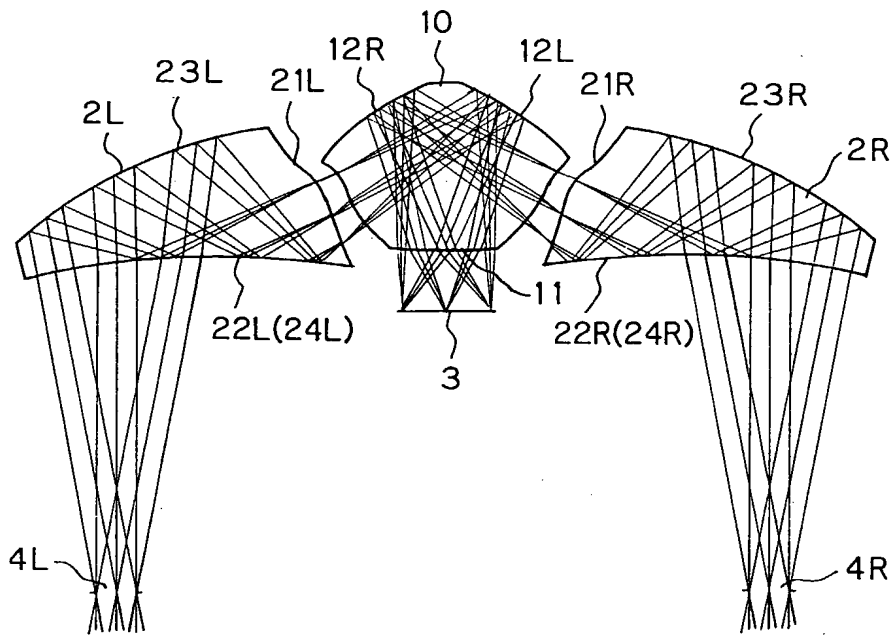
第 1 6 図



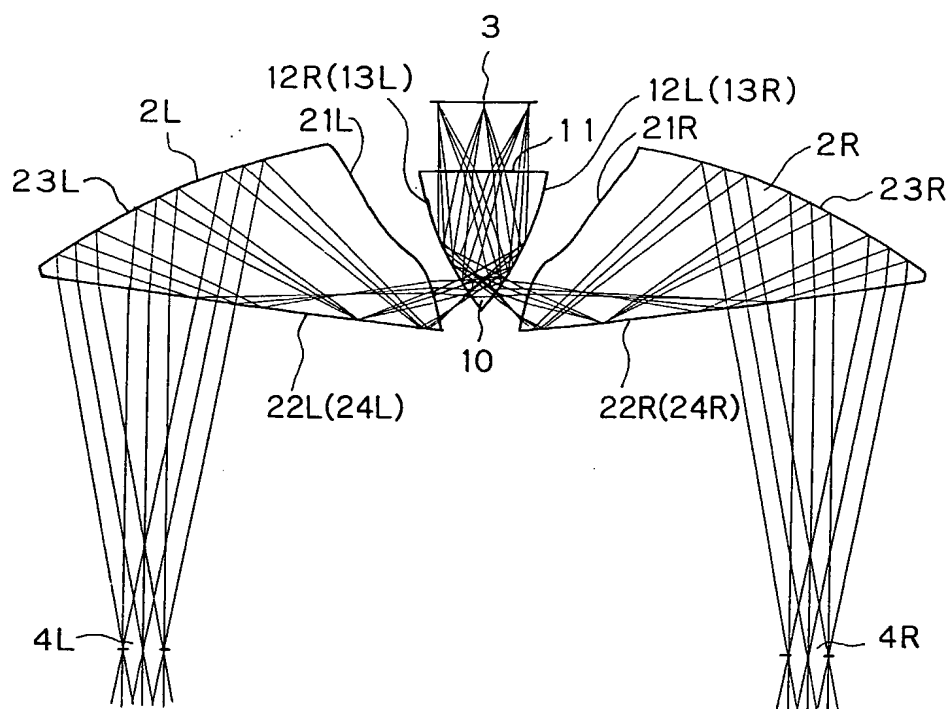
第 1 7 図



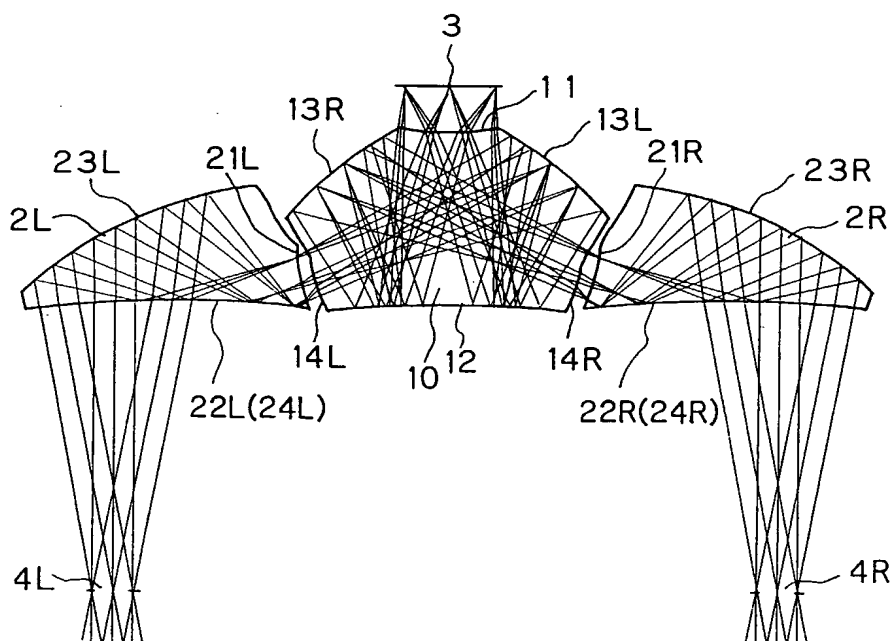
第 1 8 図



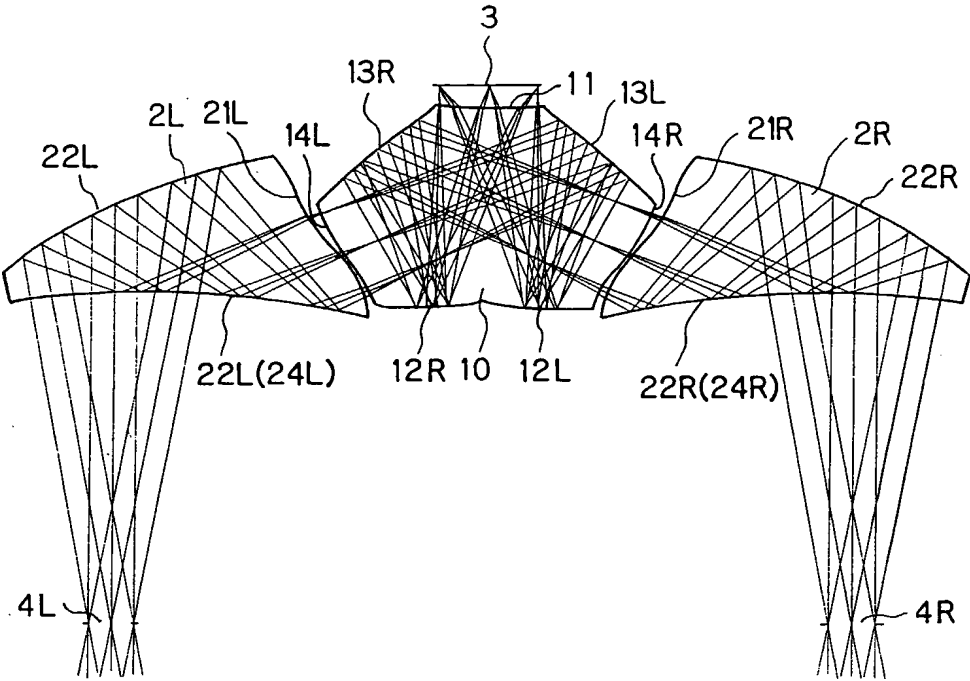
第 1 9 図



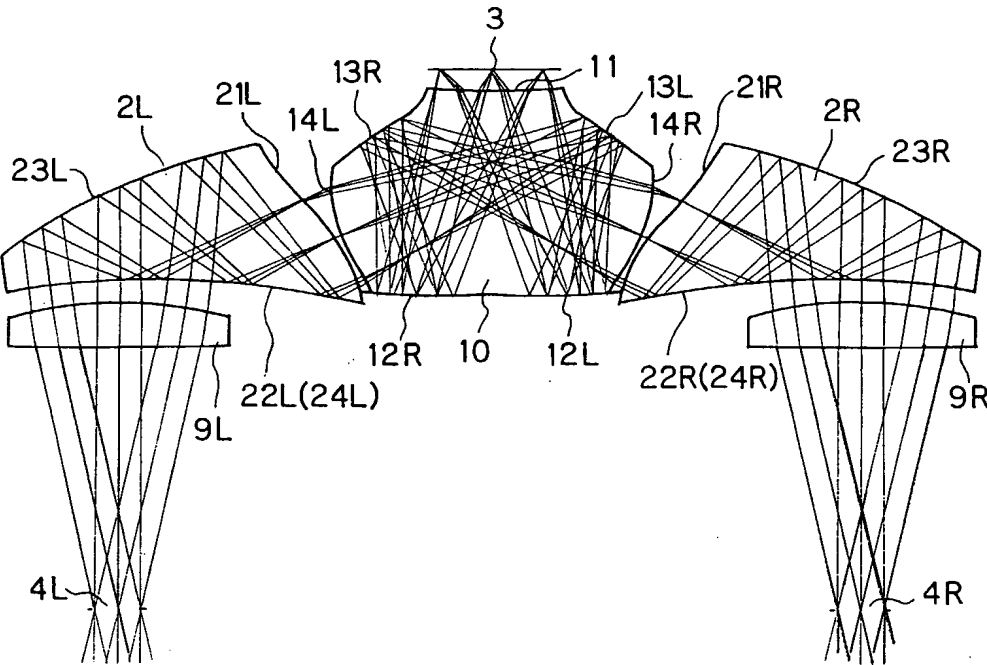
第 2 0 図



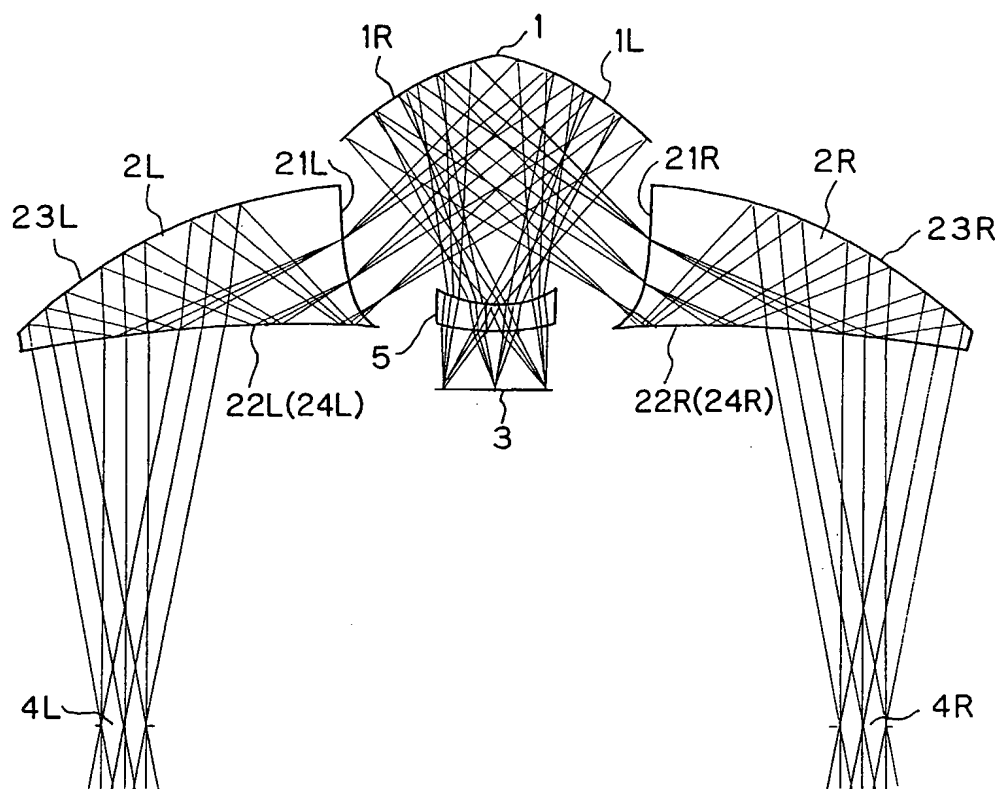
第 2 1 図



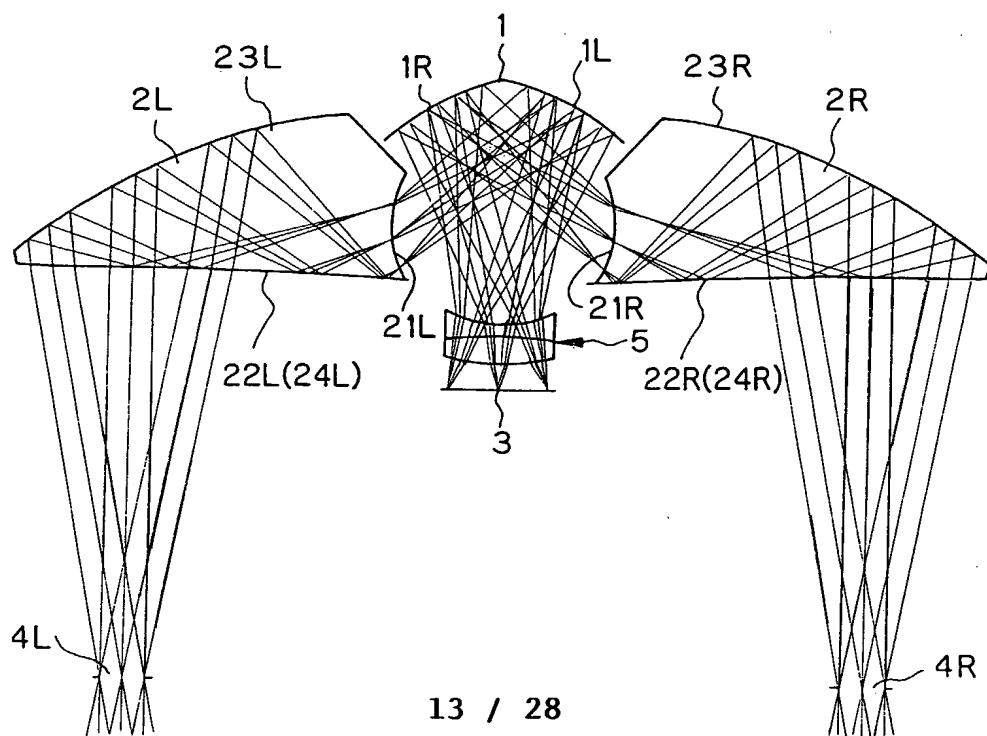
第 2 2 図



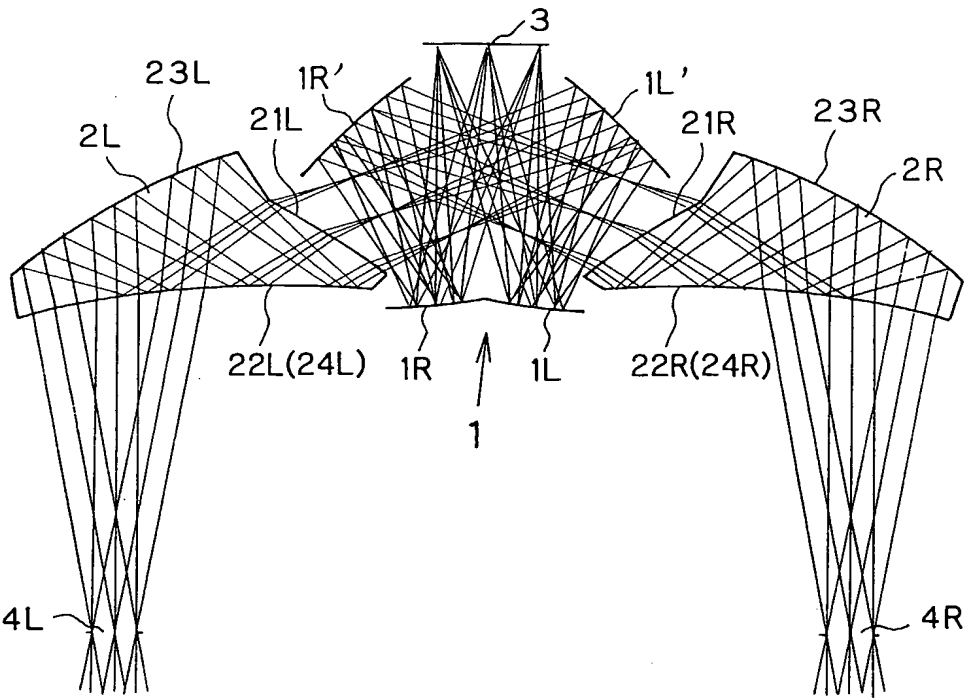
第 2 3 図



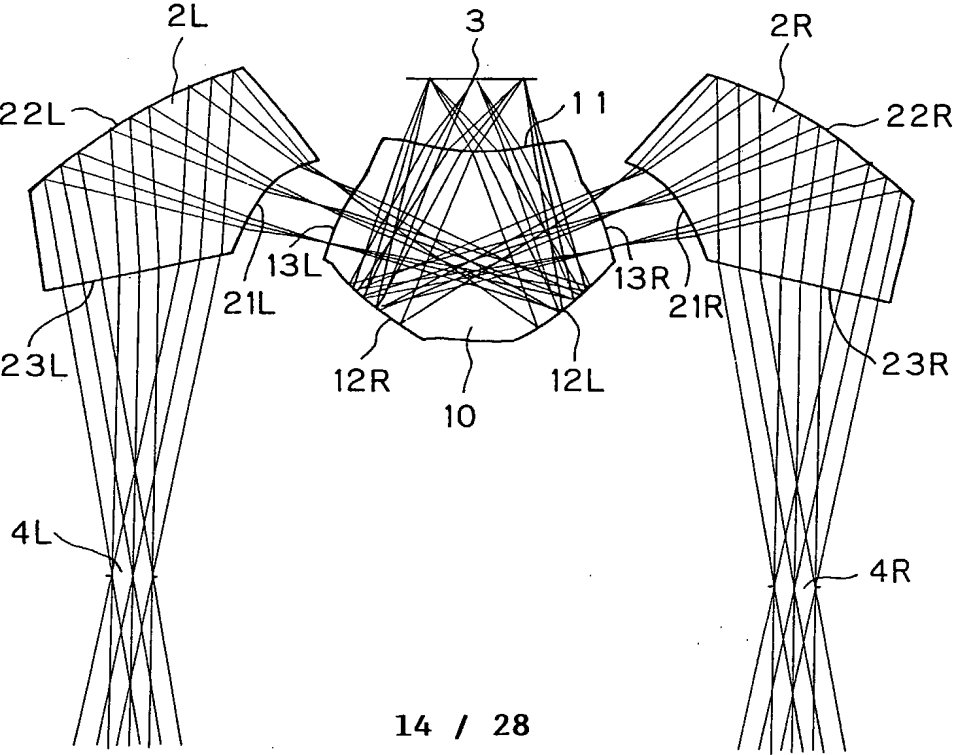
第 2 4 図



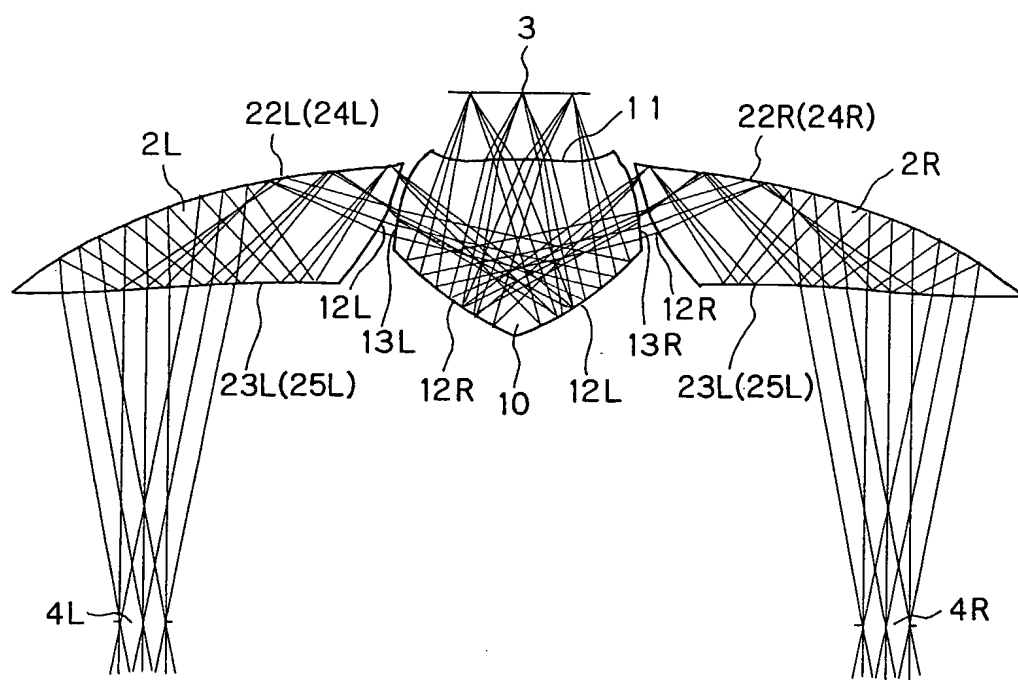
第 2 5 図



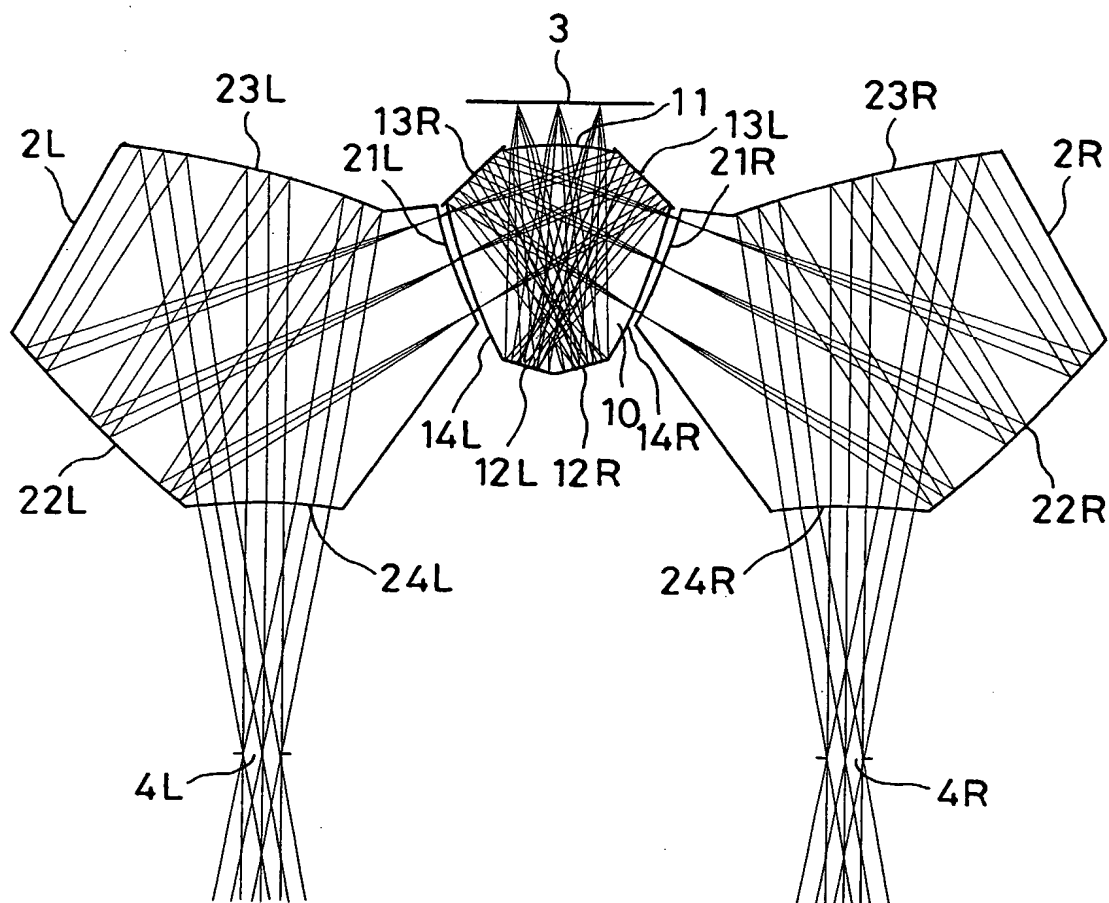
第 2 6 図



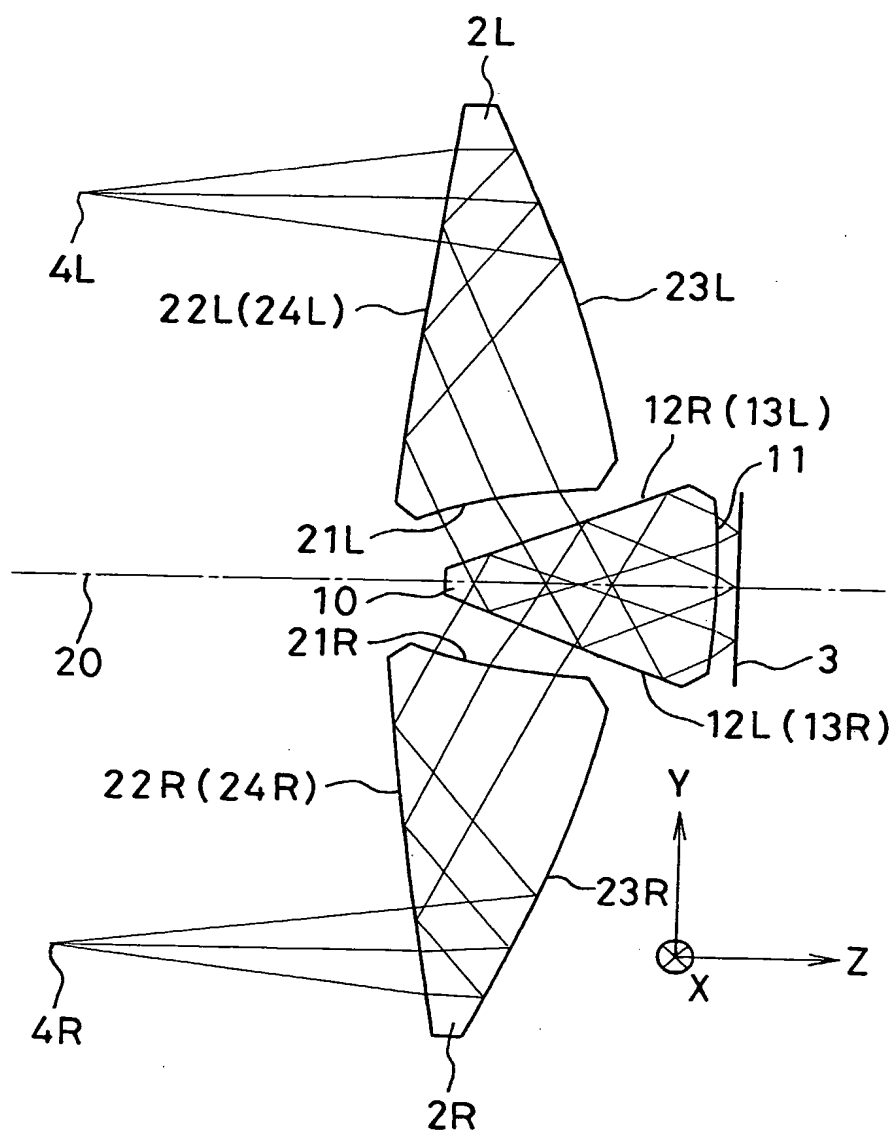
第 2 7 図



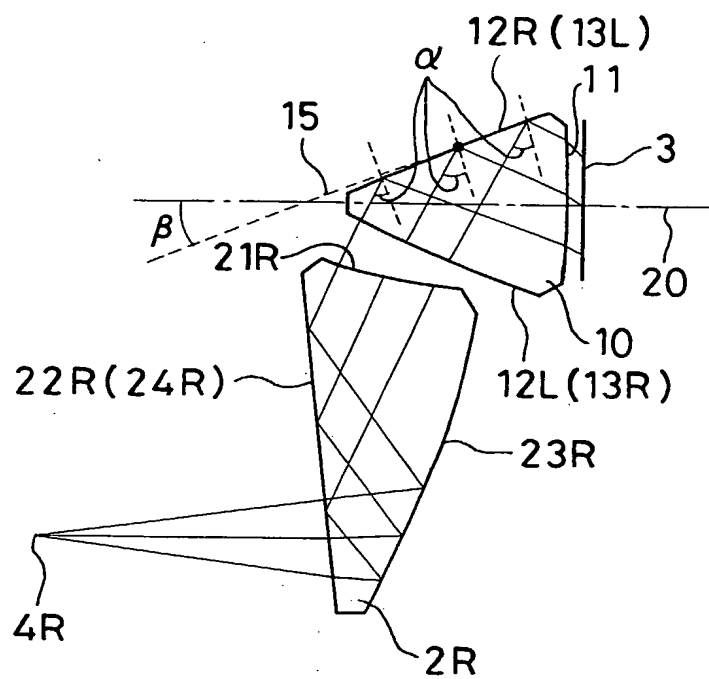
第 28 図



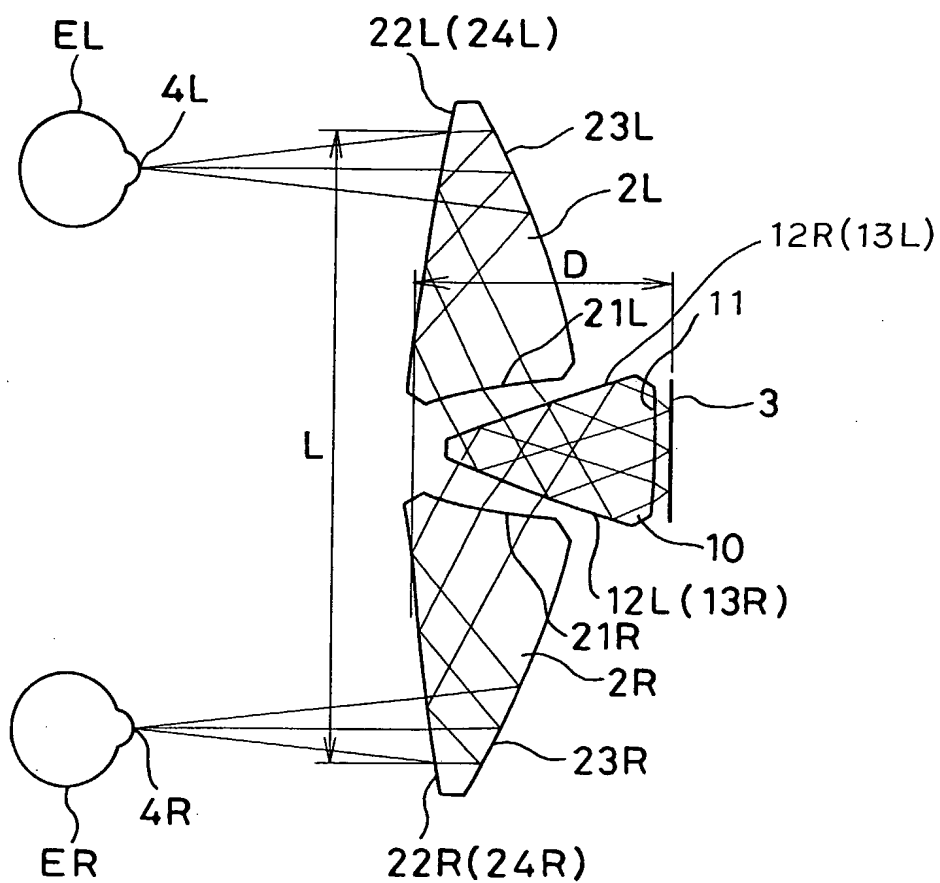
第 2 9 図



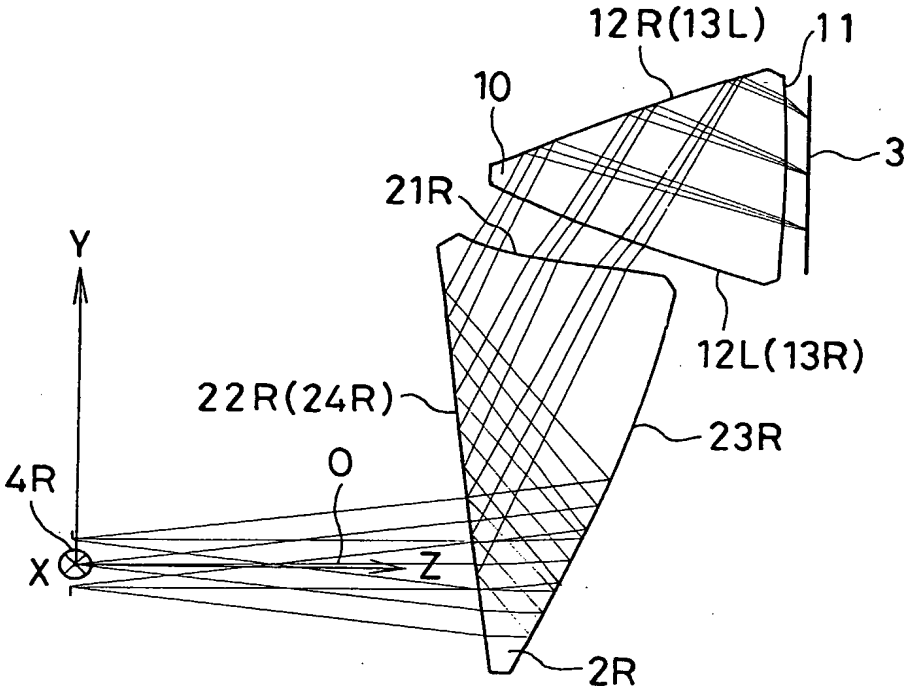
第 3 0 図



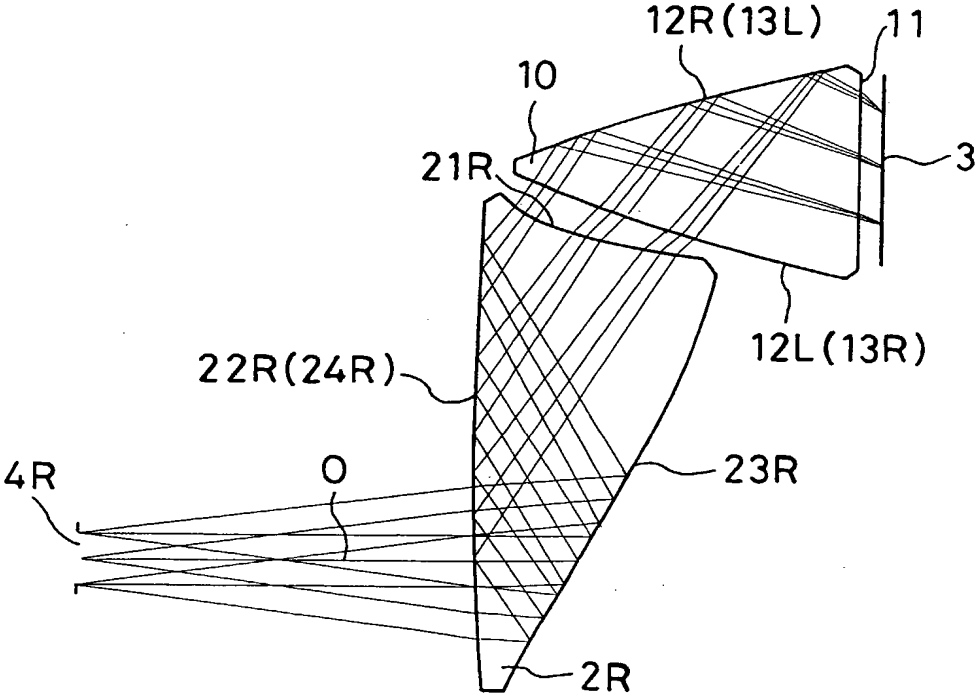
第 3 1 図



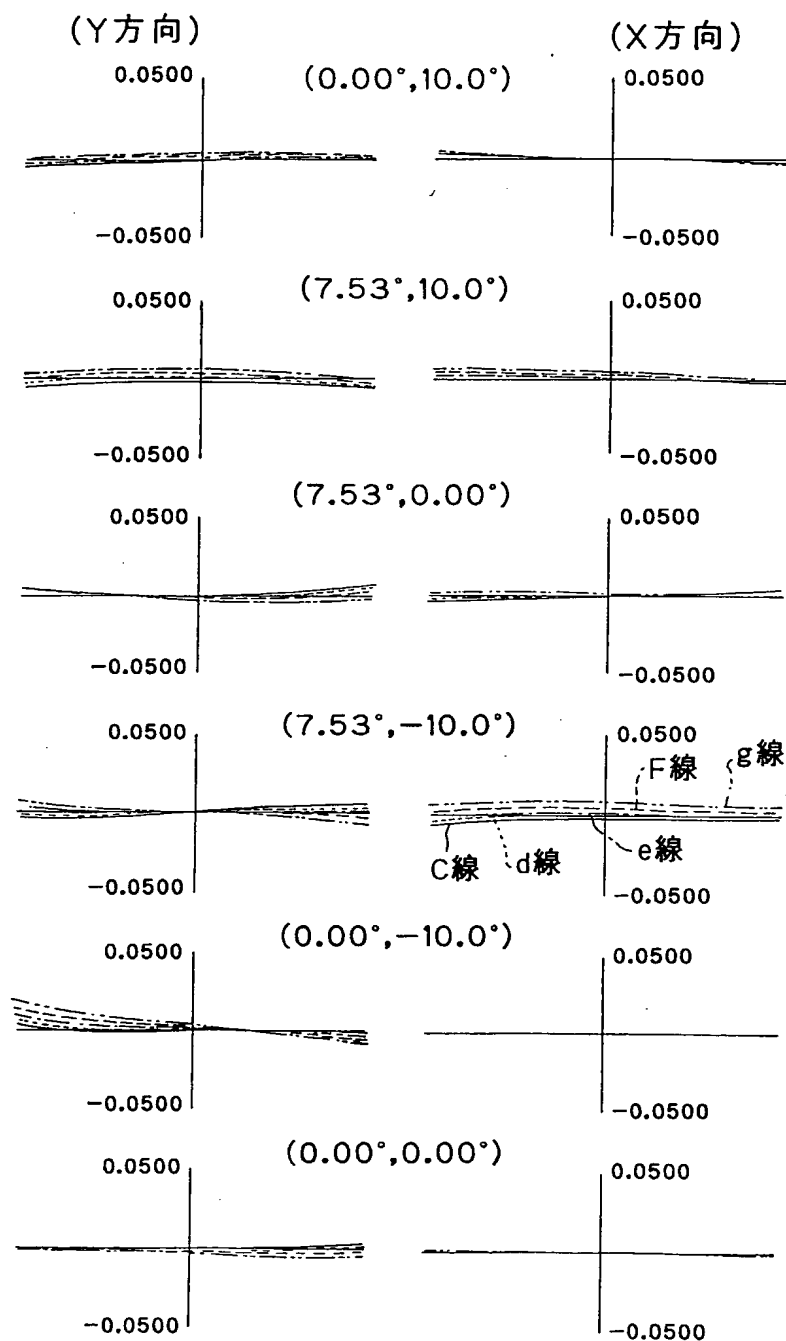
第 3 2 図



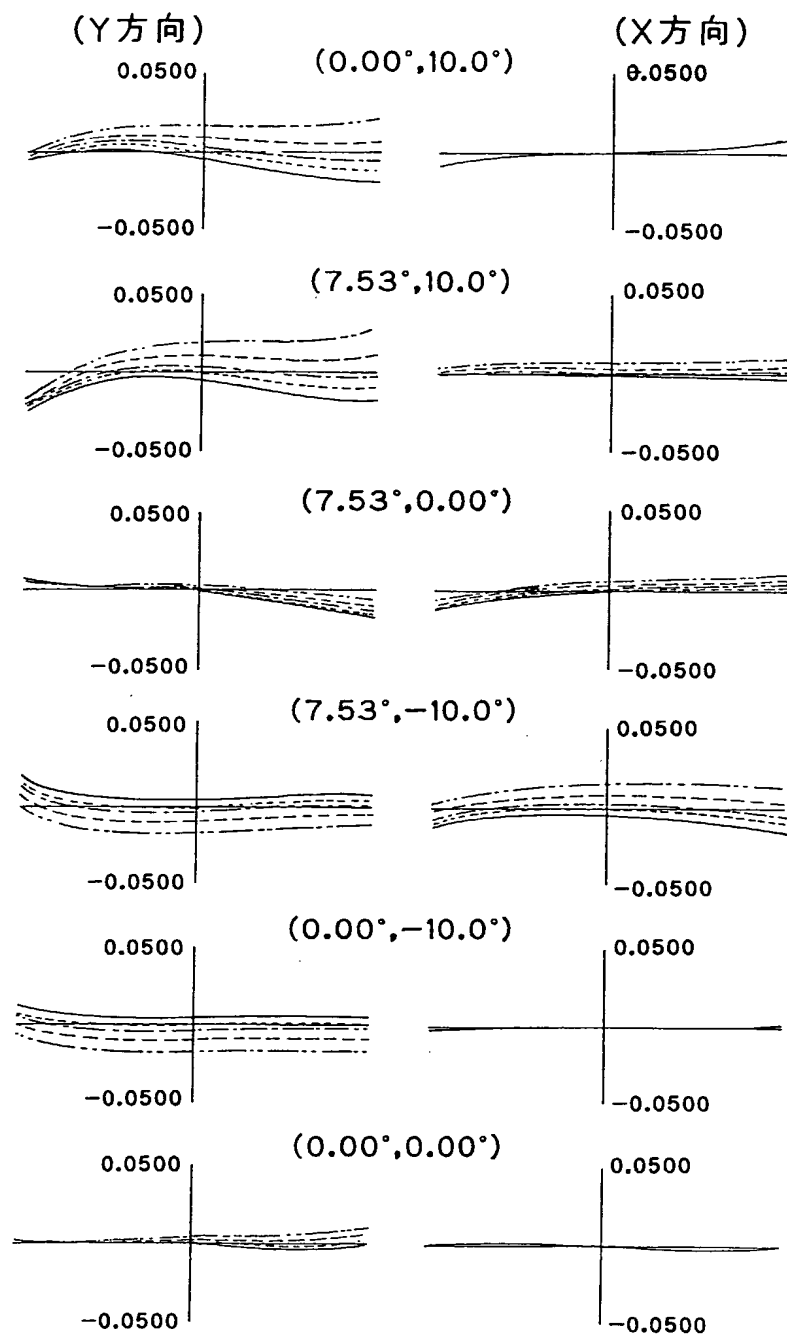
第 3 3 図



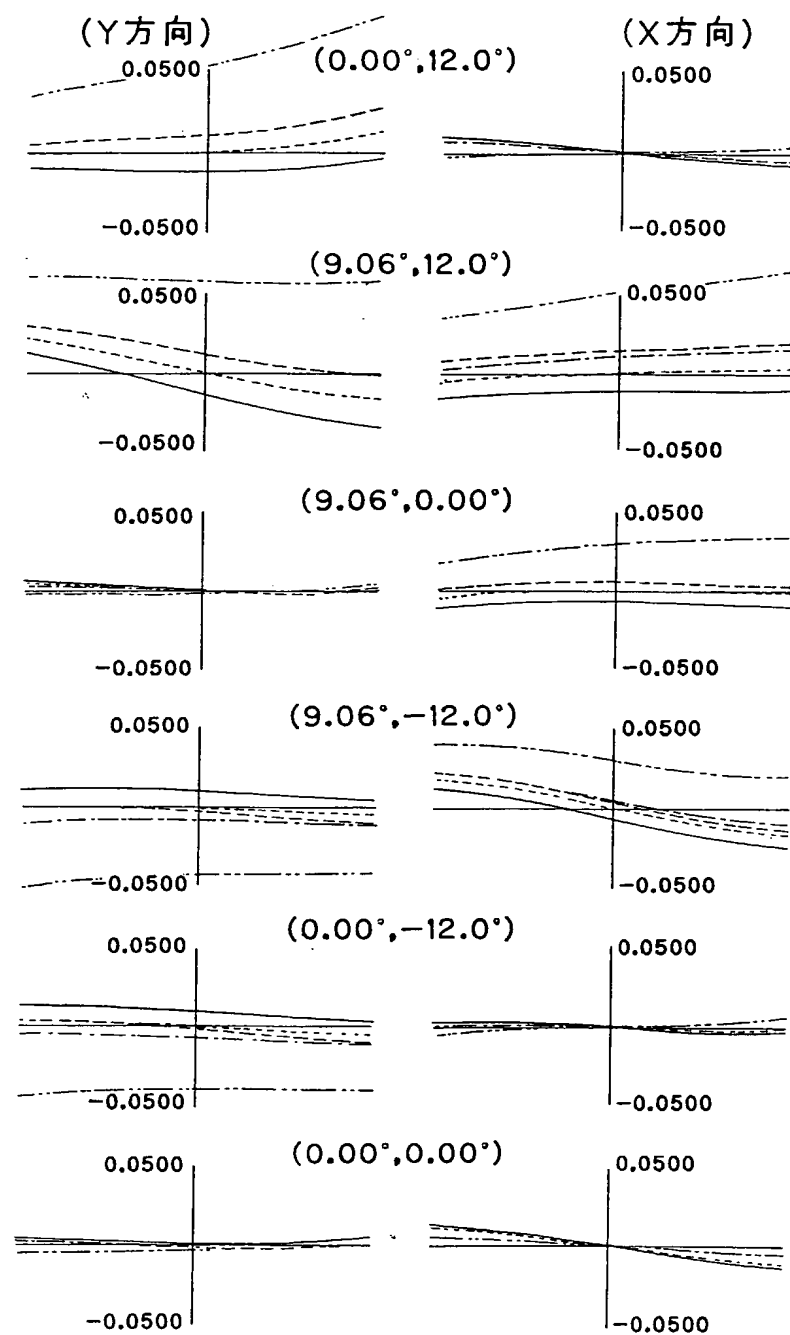
第 3 4 図



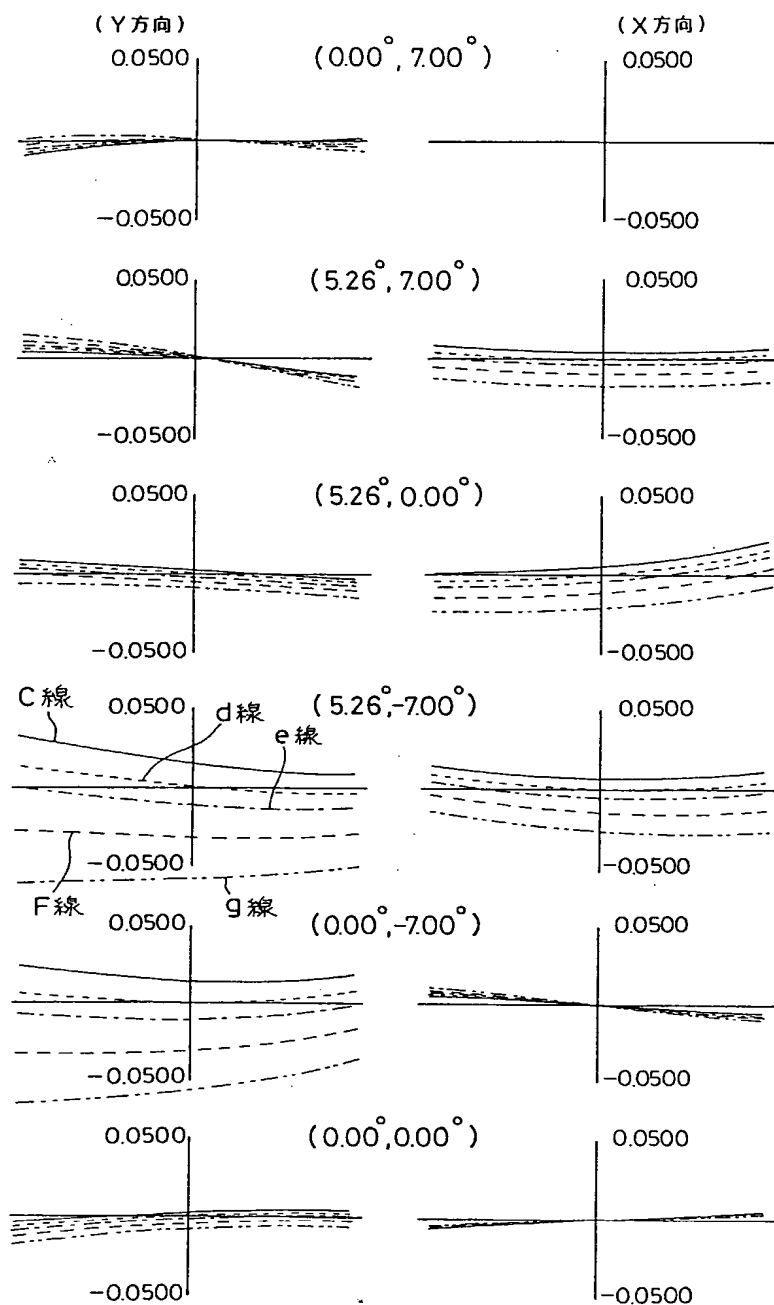
第 3 5 図



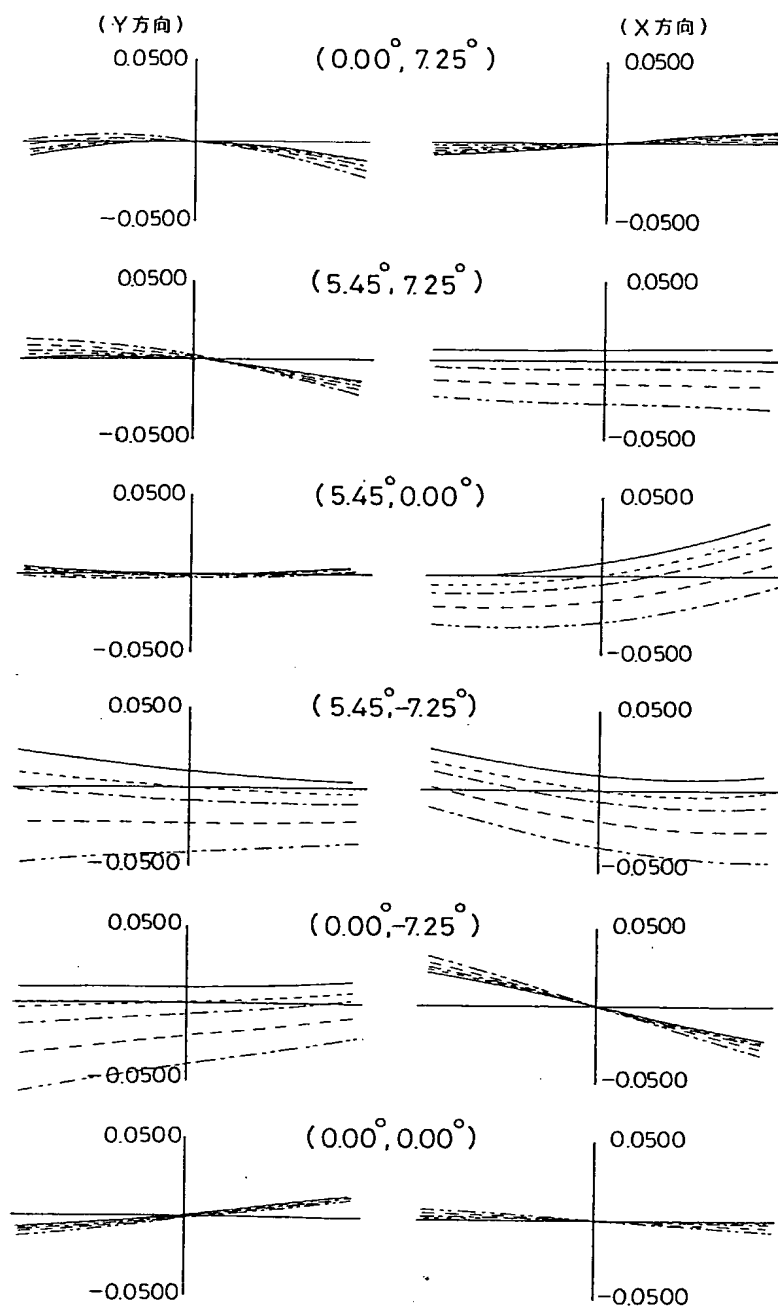
第 3 6 図



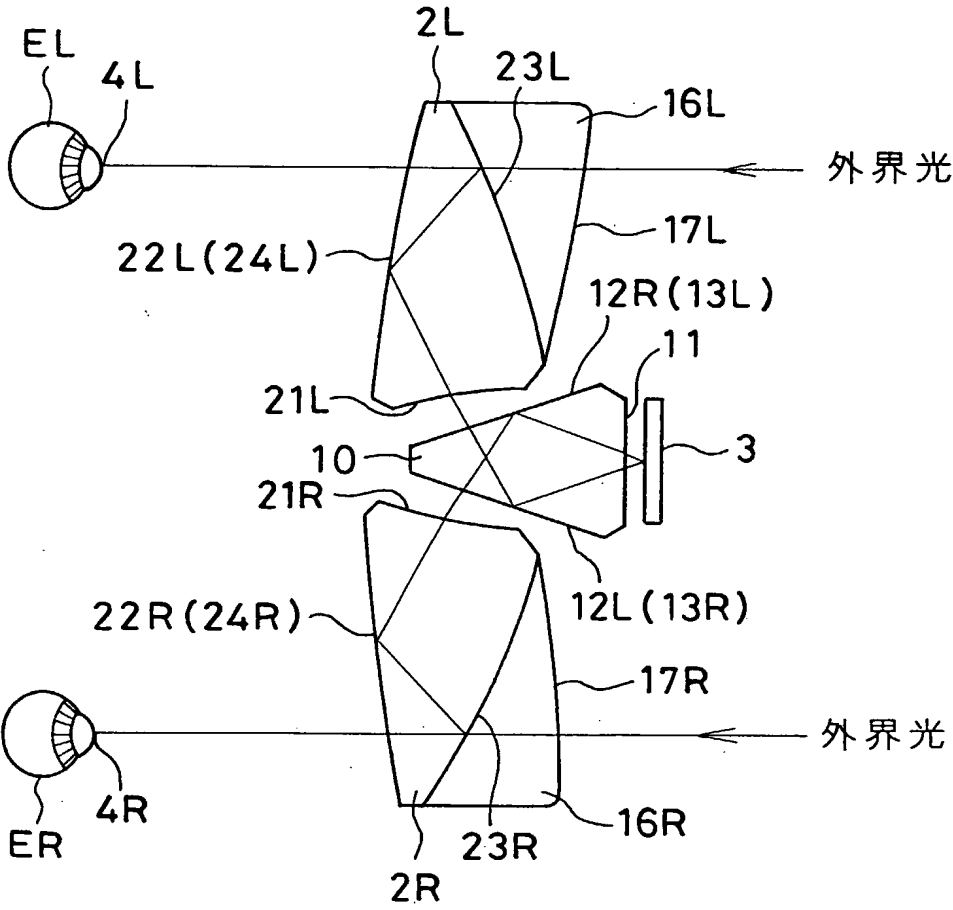
第 3 7 図



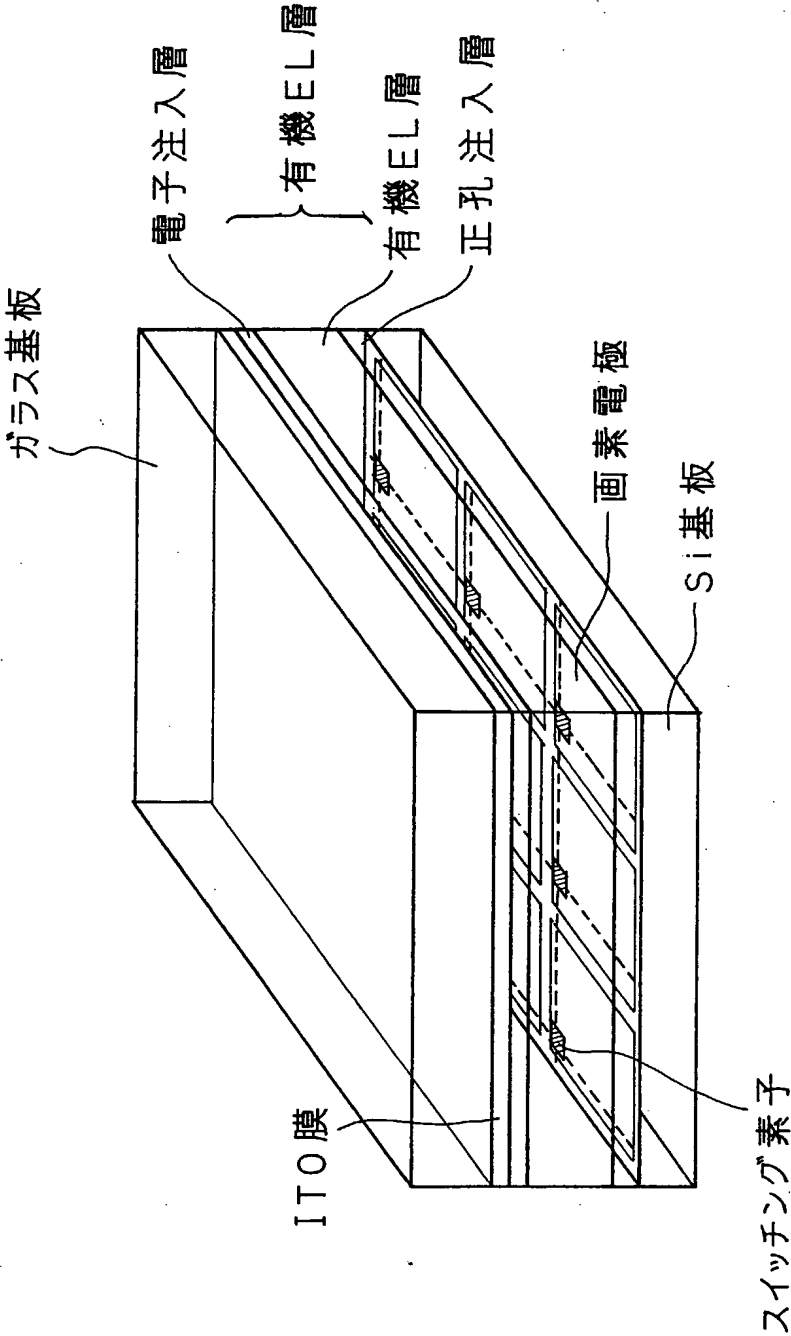
第 38 図



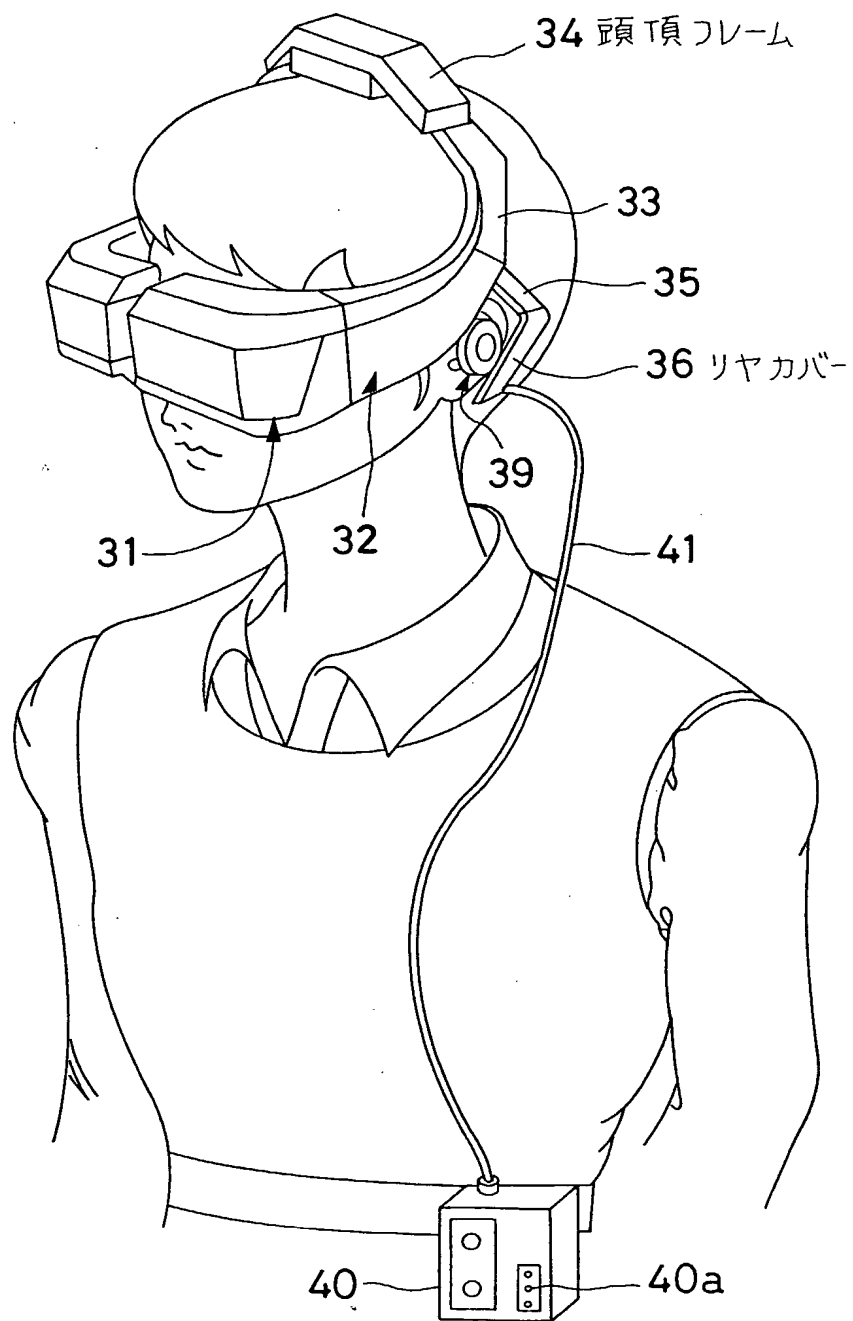
第 3 9 図



第40図



第 4 1 図



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP00/02549

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl⁷ G02B 27/02 G09F9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl⁷ G02B 27/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1991-1996 Toroku Jitsuyo Shinan Koho 1994-2000
Kokai Jitsuyo Shinan Koho 1991-2000 Jitsuyo Shinan Toroku Koho 1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 10-282421, A (Olympus Optical Company Limited), 23 October, 1998 (23.10.98), Full text; Figs. 1 to 25 (Family: none)	1-53
A	JP, 9-61748, A (Olympus Optical Company Limited), 07 March, 1997 (07.03.97), Full text; Figs. 1 to 16 (Family: none)	1-53
A	JP, 7-287185, A (Sony Corporation), 31 October, 1995 (31.10.95), Full text; Figs. 1 to 11 (Family: none)	1-53
A	JP, 6-110013, A (Sega Enterprise Ltd.), 22 April, 1994 (22.04.94), Full text; Figs. 1 to 4 (Family: none)	1-53
A	JP, 5-176260, A (Sega Enterprise Ltd.), 13 July, 1993 (13.07.93), Full text; Figs. 1 to 3 (Family: none)	1-53

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
18 July, 2000 (18.07.00)

Date of mailing of the international search report
01 August, 2000 (01.08.00)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

A. 発明の属する分野の分類 (国際特許分類 (IPC))
Int. Cl⁷ G02B 27/02 G09F9/00

B. 調査を行った分野

調査を行った最小限資料 (国際特許分類 (IPC))
Int. Cl⁷ G02B 27/02

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報 1991-1996年
日本国公開実用新案公報 1991-2000年
日本国登録実用新案公報 1994-2000年
日本国実用新案登録公報 1996-2000年

国際調査で使用した電子データベース (データベースの名称、調査に使用した用語)

C. 関連すると認められる文献

引用文献の カテゴリー*	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
A	JP, 10-282421, A (オリンパス光学工業株式会社) 23. 10月. 1998 (23. 10. 98) 全文、第1-25図 (ファミリーなし)	1-53
A	JP, 9-61748, A (オリンパス光学工業株式会社) 7. 3月. 1997 (07. 03. 97) 全文、第1-16図 (ファミリーなし)	1-53

☒ C欄の続きにも文献が列挙されている。

☐ パテントファミリーに関する別紙を参照。

* 引用文献のカテゴリー

「A」 特に関連のある文献ではなく、一般的技術水準を示すもの

「E」 国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの

「L」 優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献 (理由を付す)

「O」 口頭による開示、使用、展示等に言及する文献

「P」 国際出願日前で、かつ優先権の主張の基礎となる出願

の日の後に公表された文献

「T」 国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの

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「&」 同一パテントファミリー文献

国際調査を完了した日

18. 07. 00

国際調査報告の発送日

01.08.00

国際調査機関の名称及びあて先

日本国特許庁 (ISA/JP)

郵便番号100-8915

東京都千代田区霞が関三丁目4番3号

特許庁審査官 (権限のある職員)

瀬川 勝久



2X

9120

電話番号 03-3581-1101 内線 3295

C (続き) . 関連すると認められる文献		
引用文献の カテゴリー*	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
A	JP, 7-287185, A (ソニー株式会社) 31. 10月. 1995 (31. 10. 95) 全文、第1-11図 (ファミリーなし)	1-53
A	JP, 6-110013, A (株式会社セガエンタープライゼ ズ) 22. 4月. 1994 (22. 04. 94) 全文、第1-4図 (ファミリーなし)	1-53
A	JP, 5-176260, A (株式会社セガエンタープライゼ ズ) 13. 7月. 1993 (13. 07. 93) 全文、第1-3図 (ファミリーなし)	1-53